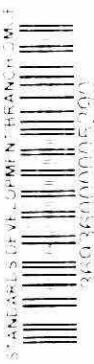


J. M. DONALD



**Acid Particulate and
Particle Sizing
Sampling at
INCO Superstack, June, 1977**

REPORT NUMBER ARB-TDA 53-78

February 1978

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Ontario

**Ministry
of the
Environment**

The Honourable
Harry C. Parrott, D.D.S.,
Minister
K.H. Sharpe,
Deputy Minister

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AIR RESOURCES BRANCH

Source Assessment Unit
Technology, Development and Appraisal Section

Report No. ARB - TDA 53-78

ACID PARTICULATE AND PARTICLE SIZING

SAMPLING AT

INCO SUPERSTACK, JUNE, 1977

Ministry of the Environment
880 Bay St., 4th Floor
Toronto, Ontario
M5S 1Z8

February, 1978

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01. SUMMARY

As part of the Sudbury Environmental Study Programme for 1977, three series of tests were conducted at a single point in the south quadrant at the 80 meter level of the INCO superstack. The sampling was carried out by INCO personnel under the direction of the Ministry of the Environment. All samples were returned to the Air Quality Section of the MOE Laboratory Services Branch for analysis; in some cases, residues were given to INCO's laboratory for comparative purposes.

Calculated rates and concentrations of sulfuric acid were 104.6 g/s and .057 g/st'd m³ for Test #1; 103.2 g/s and .058 g/st'd m³ were derived during Test #2. Both tests were of a two hour duration. However, the accuracy of the sulfuric acid method has been questioned and these levels should be taken with caution until confirmed by further testing.

Particulate data were collected during both the acid test and two six hour particulate tests. The resultant calculated rates had a mean of 355 g/s, with a standard deviation of 48.0; the second particulate test had the greatest variation from this mean (68.7 g/s) or about 1.43 times the standard deviation found over the four tests. Similarly, the mean concentration over four tests was .1935 g/st'd m³, with a standard deviation of .0248: again, the second particulate test yielded the highest concentration (.277 g/st'd m³) with a deviation of about 3.37 times the standard deviation. The emission levels of particulate determined in a single acceptable test in 1976 were 76.0 g/s and .101 g/st'd m³, about 50% of that found in 1977.

Trace metal data were also obtained during the acid and particulate tests. Mean emission rates for selected elements from the four tests were: Copper 11.42 g/s (std. deviation 2.87), Nickel 9.22 g/s (std. dev. 1.27), Lead 4.89 g/s (std. dev. 1.81), Zinc 2.96 g/s (std. dev. .738), Iron 39.37 g/s (std. dev. 4.33) and Arsenic, 2.25 g/s (std. dev. 1.9). Note the large deviation in arsenic data. Emission rates for 18 elements, accumulated over four tests, can be found in Table 2.

A plot of aerodynamic diameter vs. cumulative percent obtained from the data of particle sizing test #3 is shown in Figure 1, Page 5. Although three particle sizing tests were performed the second and first tests had anomalies in the inlet weights, and, in addition, test #2 had poor isokinetics. Thus test #3 was considered the only one representative of the source. The mass media diameter obtained during this test is quite large (8.0 microns) as shown in Figure 1. Also, a considerable fraction of the sample (45%) has an aerodynamic diameter in excess of 10 microns Comparable data obtained during 1976 gave an average mass median diameter of 5.0 microns and an average of 31% of the particles with an equivalent diameter in excess of 10 microns.

Data on sulphur dioxide emissions over the test period were obtained from the output of INCO's continuous monitor. (See Appendix 3). Emission rates varied from a maximum of 4544 tonnes per day to a low of 1446 tonnes per day, with a mean of 2894 tonnes per day. SO₂ emission data collected in 1976 were within these limits and had a mean of 2765 tonnes per day.

TABLE 1.

SUMMARY OF INCO SUPERSTACK TEST DATA

- June 1977

<u>ACID EMISSION</u>	<u>RATE</u>	<u>CONCENTRATION</u>
Acid Test #1 June 7, 1977	104.6 g/s	.0570 g/st'd m ³
Acid Test #2 June 9, 1977	103.2 g/s	.0582 g/st'd m ³

PARTICULATE EMISSIONS (not including Impingers)

	<u>RATE g/s</u>	<u>CONCENTRATION</u>
Acid Test #1 June 7, 1977	329.1	.179 g/st'd m ³
Acid Test #2 June 9, 1977	351.2	.197 g/st'd m ³
Particulate #1, June 6, 1977	316.0	.171 g/st'd m ³
Particulate #2, June 8, 1977	423.7	.227

Trace Metals - See Table #2

Particle Sizing - Mass Median Diameter

Test #3 June 10, 1977- 8.8 microns

Plot of Particle Size vs. Cumulative Percent Follows

TABLE: 2

EMISSION OF TRACE METALS - INCO SUPERSTACK - June, 1977

Element	Acid Test #1 g/s	Acid Test #2 g/s	Particulate Test #1 g/s	Particulate Test #2 g/s
Cd	.481	.325	.479	.228
Cr	.716	1.27	.368	.154
Cu	14.95	9.06	9.106	12.58
Pb	4.36	3.26	4.45	7.48
Mn	.121	.099	.124	.067
Zn	3.53	2.08	3.500	2.718
Al	4.08	3.76	.887	1.448
Bi	2.20	2.12	.536	.935
Si	21.53	100.6	2.90	3.143
Ca	1.248	1.31	2.052	2.738
Co	.307	.506	.257	.295
Fe	43.34	38.31	33.72	42.11
K	1.09	1.03	.554	.697
Mg	1.60	1.40	1.593	1.542
Ni	9.80	10.34	7.427	9.304
V	.274	.205	.219	.403
Na	1.77	.6601	.1115	.176
As ¹	2.48*	N/A	.167 *	4.10

Note: In cases where levels detected in a particular train component wash were reported as lower than the detection limit, these levels were taken as zero when determining the total catch of a specific element.

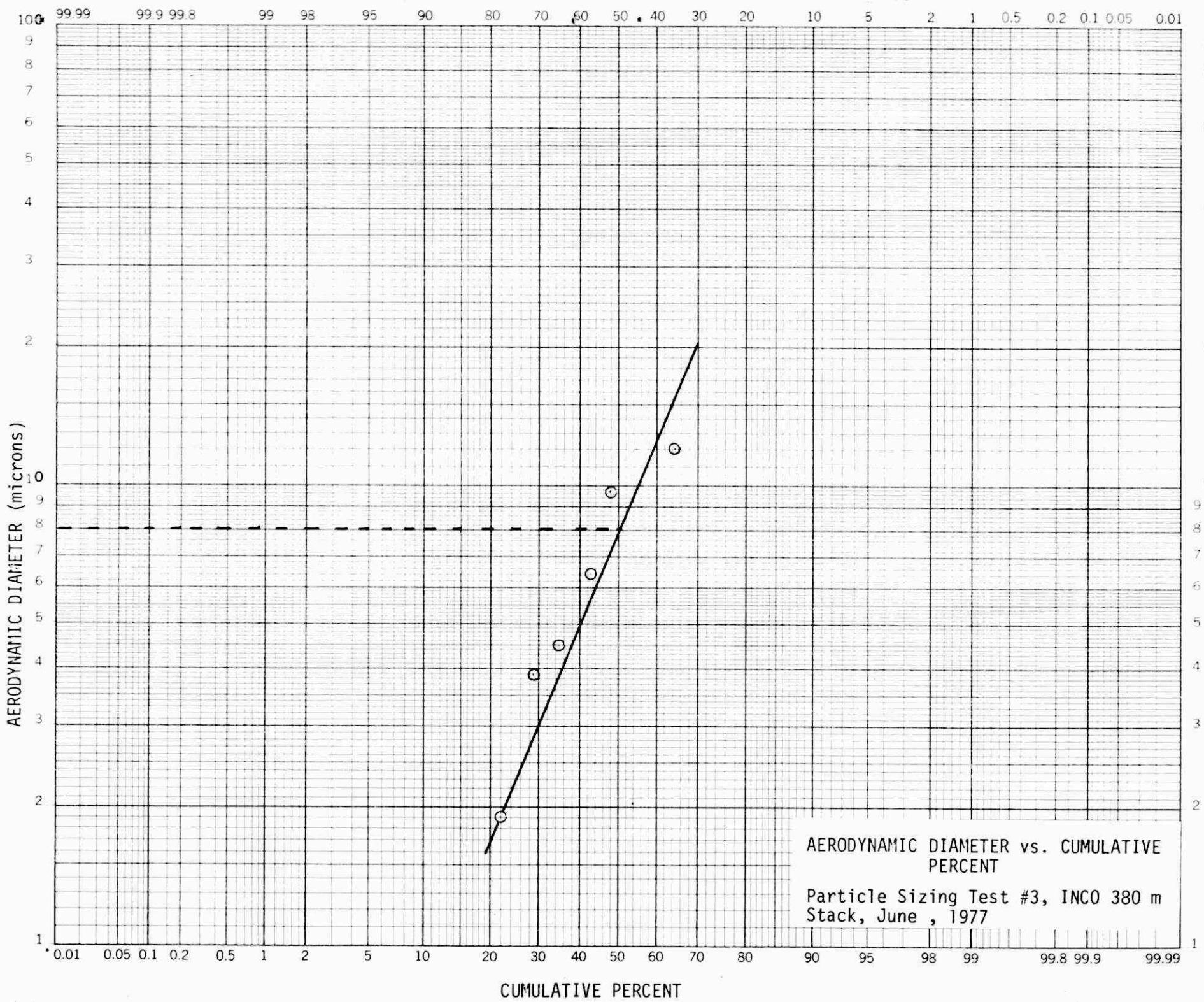
- 1 Arsenic analyses procedure altered-analyses performed twice
data reported here is result of second analyses

* Incomplete sample for second analyses
o Analyzed by Inco using MOE procedure

N/A - unable to obtain second analyses for arsenic from Acid #2 samples

FIGURE 1

- 5 -



2.0 CONCLUSIONS:

In reviewing the 1977 test program at the INCO Superstack, the following conclusions were reached:

- (1) Levels of sulfuric acid determined in the stack gases appear to be low, based on a review of data from previous years. Thus the values derived during the 1977 program for acid levels (.0575 g/st'd m³, 104 g/s) should be taken with caution until confirmed by further modified testing.
- (2) A careful evaluation of the testing program indicates that particulate data generated during both acid and particulate tests can be taken as representative of emission levels at the time of testing. The mean emission rate and concentration over the four tests were 355 g/s and .1935 g/st'd m³. The fact that all four tests were subisokinetic (between 91 and 97% overall) may have resulted in over estimations as great as 7%.
- (3) The first two of the three particle sizing tests yielded a total particulate loading far in excess of that found during the particulate and acid testing. Errors in recovery, and notation may have occurred; and thus it was decided to present only the results of Test #3. Data from the third test were presented unaltered. A mass median diameter of 8.0 microns resulted from this test and a considerable fraction of the particulate (45%) had an equivalent aerodynamic diameter in excess of 10 microns. However, this result should be confirmed by further testing, as outlined in the recommendations.

- (4) As mentioned previously, the data presented here in some cases can be taken as representative of emissions from this source during the test period. However, further process data are necessary before these emission levels can be taken with confidence as characteristic of the process operation on a monthly or yearly basis.

03. RECOMMENDATIONS:

- (1) The entire source sampling apparatus should be calibrated prior to any 1978 test work. This would include the probe if altered, all temperature sensing devices for measuring stack temperature, probe temperature, oven temperature, impinger temperature and meter temperature, and the dry gas meter. Procedures recommended by the Source Assessment Unit, MOE, should be used for this work.
- (2) The Source Assessment Unit will review various sulfuric acid sampling methods and select a procedure, or procedures for acid testing at the superstack. The sampling train should be modified, if necessary, to maintain a temperature of 200 °C through the filter.
- (3) In both the 1976 and 1977 particle sizing tests, calculated particulate concentrations from the test data were at least twice those found during acid and particulate testing. Particulate and acid testing were not conducted at the same time, and process variations could cause changes in particulate loading; however, none of the information available, inadequate though it is, indicates such process changes. Similarly, errors detected in the procedures, such as weight variations due to humidity and sulfonation of the glass fibre filters, are not of sufficient magnitude to account for this variation. Thus, the following procedures should be used to determine the extent of the error.
 - a) A 4.75 mm (3/16") nozzle will be used for all testing. This will allow the control module to operate at its designed flow rates.
 - b) A gooseneck nozzle (4.75 mm) should be used in place of the nozzle-cyclone combination during at least some of the tests. While the cyclone did catch some material during the test program, the amount was not large enough to make its use mandatory.

- c) The glass fibre substrates and cross bars should be eliminated from the train for some of the tests and the dry impaction plates used to collect the size fractions. Only a backup filter will be used. This could result in an increase in particle bounce and sampling time should be reduced to assure that loading on any one stage does not grossly exceed ten (10) milligrams. Stage weights should be determined immediately after testing.
- d) Particulate concentration data should be collected simultaneously by a particulate sampling train equipped with an in-stack filter. Condensibles would not be captured and the in-stack filter data may not be indicative of total particulate concentration; however it would give directly comparable concentration data.
- e) If good agreement is achieved between the Andersen impactor without substrates and the in-stack train, the experiment should be repeated using the glass fibre substrates.
- f) A filter could be placed prior to the Andersen unit to determine the effect of sulfur dioxide on glass fibre substrate weights. A volume similar to that sampled in previous tests could be passed through the unit and the weight change of the substrates determined.
- g) This work could be performed independent of the other segments of the program, preferably prior to the Sudbury Environmental Study stack sampling. Only bulk loading data are required; analysis for trace metals is not necessary.

O4. INTRODUCTION:

The data and results examined here are from 7 stack sampling tests done at the INCO Superstack in June of 1977. The testing program consisted of two acid tests, two particulate tests and three particle sizing tests.

Since the tests were not for compliance purposes, it was decided to conduct them at a single point within the south quadrant at the 80 meter level of the stack. The sampling point was approximately 2.7 m from the stack wall. Samples from all tests were analyzed by MOE laboratories for sulphate and trace metal content.

The calculations based on this sampling, which are presented here, are representative only of stack conditions existing at the time of testing. Information on SO₂ emissions from the Superstack as recorded by the INCO continuous monitoring system can be found in Appendix 3.

All emission data presented here are based on analyses performed by the Laboratory Services Branch, MOE. Comparative analyses of selected samples were carried out by the INCO Laboratory; results and comments on this work can be found in Appendix 5.

05. ACID TESTING:

05.01 Sampling Technique:

The method used for sampling sulfuric acid at this source was similar to that used in the 1976 program, being a combination of the EPA method 5(particulate) and Method 8(sulfuric acid) procedures. The train configuration is similar to that shown in Figure 2, P. 23, with the distilled water customarily used in the first two impingers replaced by a solution of 80% isopropanol in distilled water. To insure the presence of an adequate amount of absorbing solution in the impingers, testing was interrupted after one hour and 100 millilitres of isopropanol were added to each of the first two impingers. Prior to the testing, pitobes to be used in the program were calibrated by MOE personnel at the wind tunnel of the Mechanical Engineering Department, University of Toronto. Calibration data may be found in Appendix 4.

05.02 Observations During Sampling:

Each acid test was conducted isokinetically at a single point in the south quadrant over a 2 hour period. The stack temperatures reported during the first test seemed high and a check of the potentiometer revealed a calibration error of 60⁰F. Thus at the conclusion of the test all the stack temperature data from the first test were adjusted downward. The testing proceeded without further incident.

Sampling data for these Acid Tests can be found in Tables A1 and A2, Appendix 1. Analytical information may be found in Appendix 2.

05.03 Sampling Results - Presentation and Discussion:

As shown in Table 3, Page 27, isokinetic data from these two tests were disappointing, with 79 and 73 percent of the readings within the acceptable $\pm 10\%$ of isokinetic sampling rates for Acid Tests 1 and 2 respectively.

However, all the readings in Test #1, and 86% of the readings in Test #2 were within \pm 15 percent of the isokinetic sampling rate. The overall average isokinesis for Test 1 was 92%; similarly the Test #2 overall average was 95%.

Subisokinetic sampling, such as occurred in this case, generally results in an overestimation of particulate concentration. However, even in the case of Test #1, assuming an average particle size of 10 microns, the error resulting from anisokinetic sampling alone would be less than 4%, as shown in Figure 3, Page 24. A numerical technique, outlined in Reference 1, was also used and it indicated overestimation of approximately 7 percent (7%). The calibration error in the stack temperature sensing device did not have a significant effect on the isokinetic data.

Because the configuration of this train is similar to that used for particulate testing, particulate data are generated during these tests, as seen in Table 4, Page 29. Both tests show emission rates and concentrations very comparable to those found in Particulate Test #1 (329.1 g/s and .179 g/st'd m³ for Test #1, 351.2 g/s and .197 g/st'd m³ for Test #2; data from Particulate #1 were 316.0 g/s and .171 g/st'd m³).

Sulfuric acid emission data are given in Table 5, Page 30, and again, results from acid Tests #1 and #2 are quite comparable (.057 g/st'd m³, 104.6 g/s for Test #1, .058 g/st'd m³, 103.8 g/s for Test #2). These sampling data yielded a stack volume concentration of 12 ppm of acid, which does appear low in comparison to data from previous years. The two tests performed in 1977 have an acid emission rate of 104 g/s; the emission rate from testing in 1973 was 175 g/s, in 1974, 290 g/s and in 1975, 514 g/s. An Inco study in 1975 (Reference 2) also yielded concentrations of 77 ppm of acid. Tests performed in 1973 and 1974 and 1975 used an 80% isopropanol-distilled water solution with acetone washing.

Table 6, Page 31 does indicate inconsistencies in the sulfuric acid data. While in the first test, a great majority of the acid was found in the probe (77%) and only small amounts in the impingers (9.1%), the distribution varies in Test #2 (34% in probe, 53% in impingers); however, the total acid detected in each test was very comparable. Data on the sulfate catch in the probe and filter from the two particulate tests were included in Table 6 because the procedures used for these segments of the particulate train were identical to that used with the acid train. The particulate train, however, used distilled water as an absorbing medium, and thus, comparisons of the impinger acid catches in the acid and particulate tests are meaningless.

If the ratio of probe to filter catch is examined over both acid and particulate tests, a movement from 3:1 in the acid #2 Test, to 6:1 for the first acid test, to 8:1 for both particulate tests is noted. This indicates, even though probe temperatures were maintained at levels significantly higher than the dewpoint of the detected acid concentration, that the apparent probe acid catch was significant in both acid and particulate tests.

Sampling field data sheets indicate that probe and oven temperatures were in excess of 150°C (302°F) at all times during both acid tests. This temperature is slightly less than that detected in the stack and should be adequate to maintain a concentration of approximately 80 ppm of sulfuric acid (sulfur trioxide) in the vapour state at the essentially atmospheric pressures found in the Superstack (Reference 3). Thus, assuming that these reported temperatures were accurate, and that contact time and subsequent interaction with particulates captured by the filter are minimal, most of the sulfuric acid should be found in the impingers. The amount of the impinger catch in acid Test #2 (53%) conforms more closely to this theory; however, as noted above, the probe and filter acid catch is a substantial part of the

total. Moreover, even if all the sulfates detected in the impingers were taken as acid, the maximum concentration would only be 28 ppm. There is no indication of process variations which would result in such a substantial reduction of acid emissions over the years. At this time, the acid emission data obtained during the 1977 program should be taken as a lower limit pending further review.

As a result of the uncertainties surrounding these data, the Technology Development and Appraisal Section, MOE, has initiated a research program to simulate Superstack acid test conditions in the laboratory. The results of this program should indicate both the source and the magnitude of error in previous acid tests.

Since it is doubtful that the research data will be available to revise the 1978 S.E.S. program, acid testing will be performed using a procedure largely identical to that employed in 1976 and 1977. However, if possible, the heating capacity of the sampling train should be improved so that a temperature in excess of 177⁰C can be maintained up to and through the filter segment and a second filter medium should be placed between the first and second impingers. The use of quartz filter media during the acid tests should be studied. Simultaneous condensation acid sampling, as outlined in Reference 2, will also be considered.

06. PARTICULATE TESTING:

06.01 Sampling Technique:

Sampling was done using a standard EPA type particulate sampling train as shown in Figure 2. A teflon lined sampling probe and a Gelman Spectro Grade 'A' glass fibre filter were used in this train. The balance of the components was glass. Distilled water was used as the absorbing medium in the impingers.

06.02 Observations During Sampling:

The same calibration error in the stack temperature sensing equipment which affected the first acid test also affected both particulate tests. In treating the data, 60⁰F was subtracted from all the stack temperatures detected during both tests. Sample recovery and analysis were carried out as outlined in Appendix 2. Field sampling data are given in Appendix 1. Note that the stack temperatures given in these data have been corrected for the calibration error.

06.03 Sampling Results - Presentation and Discussion:

Analysis of the particulate test samples was carried out as outlined in Appendix 2.

Table 3, Page 27 , Summary of Isokinetic Sampling Rates, indicates that for Particulate Tests #1 and #2, 83 and 86 percent of the readings were within acceptable isokinetic limits of $\pm 10\%$ of the stack velocity. Some improvement in these data could have been anticipated, given the accumulated sampling experience at this site. However, applying an analysis similar to that used on the acid isokinetic data, the resulting error would be less than 5%. Overall, the sampling was subisokinetic in both cases (97.25% for Test 1, 96.67% for Test 2), indicating that particulate emissions may be

slightly overestimated.

Table 4, Page 29, Emission Rates of Particulate, shows that the particulate emission rate and concentration for Test #1 are very comparable to those found in Acid Tests 1 and 2 (rate of 316 g/s, compared to 329.1 and 351.2 g/s, concentrations of .171 g/st'd m³ as compared to .179 and .197 g/st'd m³). Particulate emission rates and concentrations for Particulate Test #2 were somewhat higher (423.7 g/s , .227 g/st'd m³). Stack gas temperature varied markedly between the acid tests and the particulate tests. This would result in higher velocities and flow rates for the particulate tests and thus higher emission rates and increased sampled volume, however; the test data do indicate an increase in particulate concentration in the stack during Particulate Test #2.

Table 7, Page 32, Distribution of Particulate Matter in the Sampling Train, indicates that in both tests, significant amounts of condensable and fine particulate matter were found in the impingers. Impinger contents were 42.9% (595.4 mg) of the total residue catch in Particulate Test #1 and 53.84% (1230.6 mg) of the total in Test #2.

Referring to the data in Appendix 2, a summation of the elemental amounts detected in all impinger washes and the total sulfate ion found in the impinger solution has a value of 104.4 mg for Test #1 (Total Impingers Catch, 595.4 mg) and 64.8 mg for Test #2 (Total Impinger Catch, 1239.6 mg). Selenium is not among the elements analyzed, although visible deposits were found in the glassware used during the testing. Also, silicon grease, used to improve glassware seals throughout the sampling train, could have been a significant segment of the total impinger residue.

Table 7 also indicates that approximately one third of the particulate caught during all four tests (acid and particulate) was found in the probe liner. Generally, this indicates the presence of a substantial amount of large particulate (equivalent aerodynamic diameter of 7 microns or larger) in the stack gas effluent. The presence of particles in this size range was confirmed by the particle sizing data.

As mentioned previously, trace metal emission rates for acid and particulate tests are given in Table 2. As anticipated, rates of emission of copper, iron and nickel were high, as was that for silicon. However, silicon rates showed a great deal of variation, going from a maximum of 100 g/s to a minimum of 2.9 g/s over the four tests. Also, arsenic emission rates varied by an order of magnitude over the entire test program (maximum of .624 g/s; minimum of .06 g/s). However, the balance of the trace metal emission data showed reasonable consistency from test to test.

07. PARTICLE SIZING TESTS:

07.01 Sampling Technique:

Three particle sizing tests were conducted during this program; two using a 3.175 mm diameter (1/8") sampling nozzle and one a 4.75 mm (3/16") diameter nozzle. The larger nozzle was employed to increase the sample flow rate and permit operation of the sampling train control module at rates for which it was designed. The first two test (1/8" nozzle) were to duplicate the tests performed in collecting particle sizing data in 1976. The Andersen Cascade impactor used during this testing is illustrated in Figures 3 and 4, Page 25 and 26.

07.02 Sampling Results - Presentation and Discussion:

Isokinetic data for these tests are given in Table 3. Test #2 is definitely unacceptable, with only 50% of the readings within acceptable isokinetic limits. Tests 1 and 3 had 78 and 73% of the readings within acceptable isokinetic limits respectively. The weights caught in various segments of the impactor are given in Table 8; complete sampling data can be found in Appendix 1, Tables A5, A6, and A7.

The total weights presented in Table 8 were of concern, since they were greatly in excess of anticipated levels, based on particulate concentrations derived in earlier tests, both acid and particulate. This is demonstrated in Table 9, where the highest particulate concentration found during the acid and particulate tests was used to determine a "theoretical" catch for the particle sizing tests. While data from particle sizing tests performed in 1976 have consistently indicated a concentration in excess of that detected during particulate testing by a factor of two, only the data from Test 3 of the 1977 series retained this relationship. Particulate concentrations for Test #1 and #2 were 7.5 and 6.5 times the maximum found during acid and particulate testing levels.

Table 9, Page 34, also shows that a disproportionate amount of the catch in Tests #1 and #2 was found in impactor inlet washings. This washing includes all segments of the train from the cyclone back, that is, housing, plates, spacing rings and cross bars. Thus it is impossible to determine to which segment of the impactor this weight should be assigned. The fact that the phenomenon occurred over two successive tests indicates that it is unlikely the weight gain is due to a residue from a previous test program. Weight gains in the glass fibre substrates due to absorption of sulfur dioxide have been established in similar situations, but the overall effect is slight (typically less than 2.0 milligrams per substrate) and has no bearing on this variation in inlet loadings. Wall losses during use of the Andersen unit can also be significant, but the major concern here is the magnitude of the total catch and not its distribution with the impactor.

No significant variations in the measured stack parameters occurred over the two test periods in question, nor was there any indication of a major upset in process or control equipment during these two test periods. Thus a drastic increase in particulate levels in the stack gases during these tests appears very unlikely.

A final source of error which must be considered is associated with the weighing of the samples. Unfortunately, the washing residues in question were not available for re-weighing and a check of the original laboratory records confirmed the numbers given in the laboratory report and shown in Table 8.

Of the reported weight catches for various segments of the train, the inlet loadings for Test #1 and #2 appear excessive. Using the figures given, the inlet weight, excluding that caught on the glass fibre substrates, is 71% of the total catch in Test 1 and 77% of the total catch in Test 2. This compares with an upper limit of 29% found in the three

tests performed in 1976. (See Table 10). As mentioned previously, calculated particulate concentrations for Tests 1 and 2 of 1977 are also greatly in excess of all three tests in 1976 and the third test in 1977.

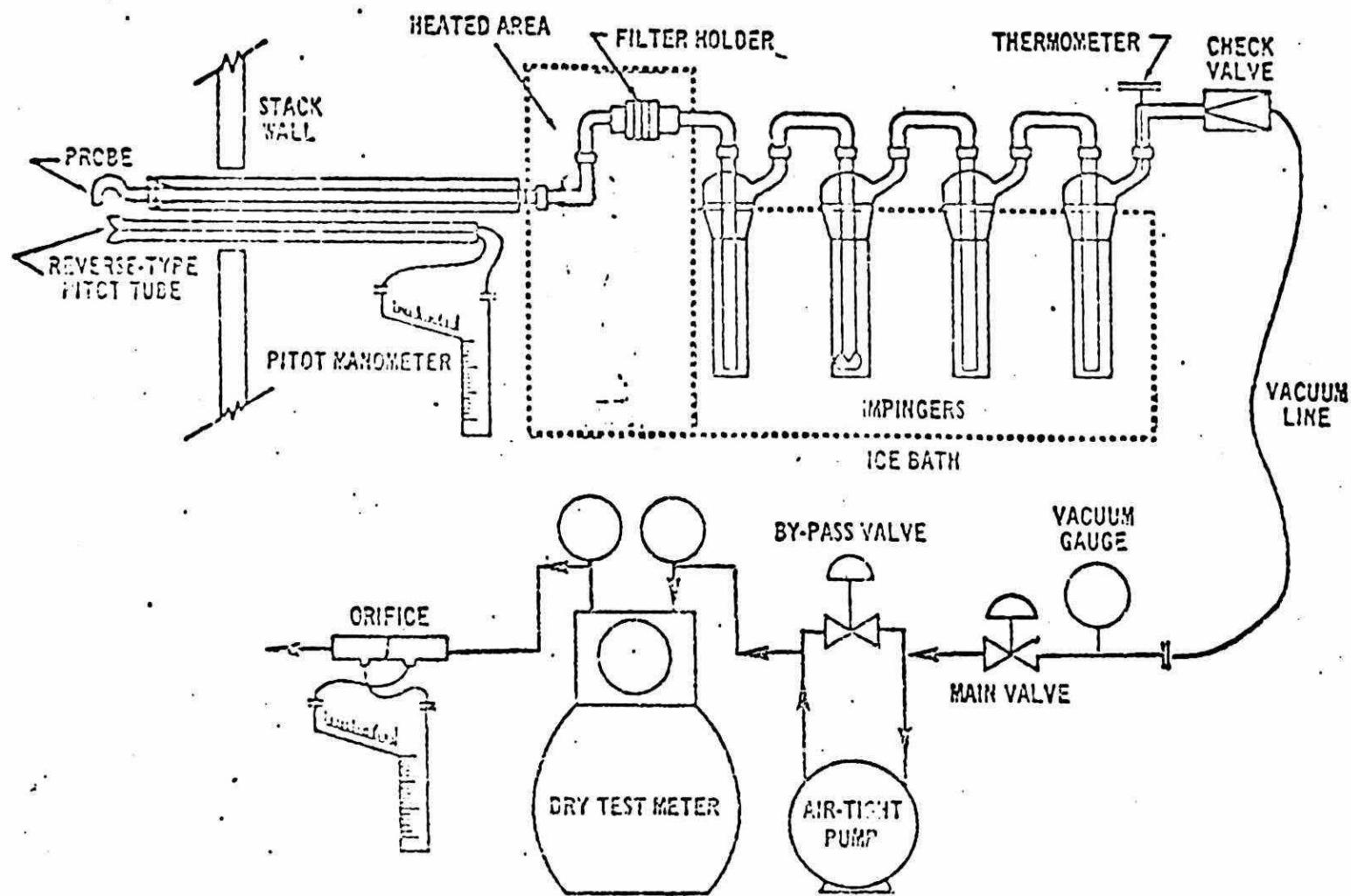
Thus, given the additional fact that the isokinetic data of test #2 were unacceptable, it was decided to eliminate both test #1 and #2 from consideration in this report. Suitable revisions will be made in the 1978 program to eliminate errors of this magnitude.

Since the collection of accurate particle sizing data at the Superstack is of high priority, and since it appears that inconsistencies have occurred in both the 1976 and 1977 testing programs, a particle sizing test program at this source is being considered for the spring of 1978. As outlined in the recommendations (Page 8), this program would involve only gravimetric determinations, using different configurations of the Andersen impactor. Sampling with a particulate train equipped with an in-stack filter will be conducted simultaneously to yield comparative particulate concentration data. Hopefully, this program will resolve the uncertainties surrounding the 1976 and 1977 size fractionation tests and suggest modifications to improve the accuracy of the particle sizing segment of the 1978 Sudbury Environmental Study Superstack series.

08 References

1. 'Estimates of Errors in Anisokinetic Sampling of Particulate Matter' by M.G. Selden, APCA Journal Volume 27, No. 3, Pg. 235, 236.
2. 'Determination of Sulphuric Acid in Stack Gas' by S. Stupavsky and V.K. Blechta, INCO Process Technology Project 047.9, issued March 24, 1976.
3. 'Flue Gas Monitoring Techniques' by John N. Driscoll, 1974, Ann Arbor Science Pub Inc., Ann Arbor Michigan, Chap. 5 Oxides of Sulfur.

FIGURE 2 SAMPLING TRAIN CONFIGURATION USED FOR ACID AND PARTICULATE TESTS



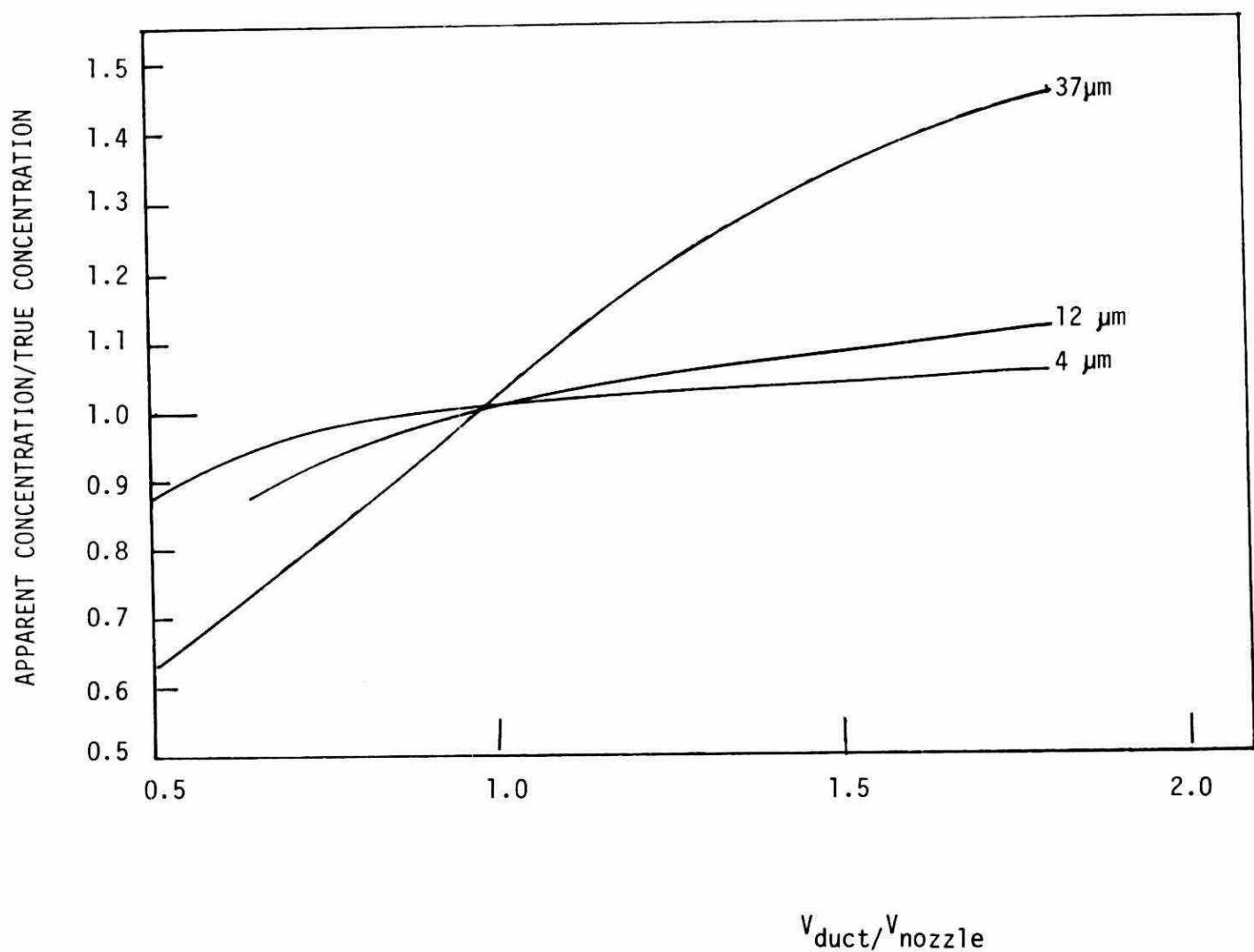


Figure 3 Sampling Errors Resulting From Isokinetic Deviations
(Source Assessment Unit Internal Document)

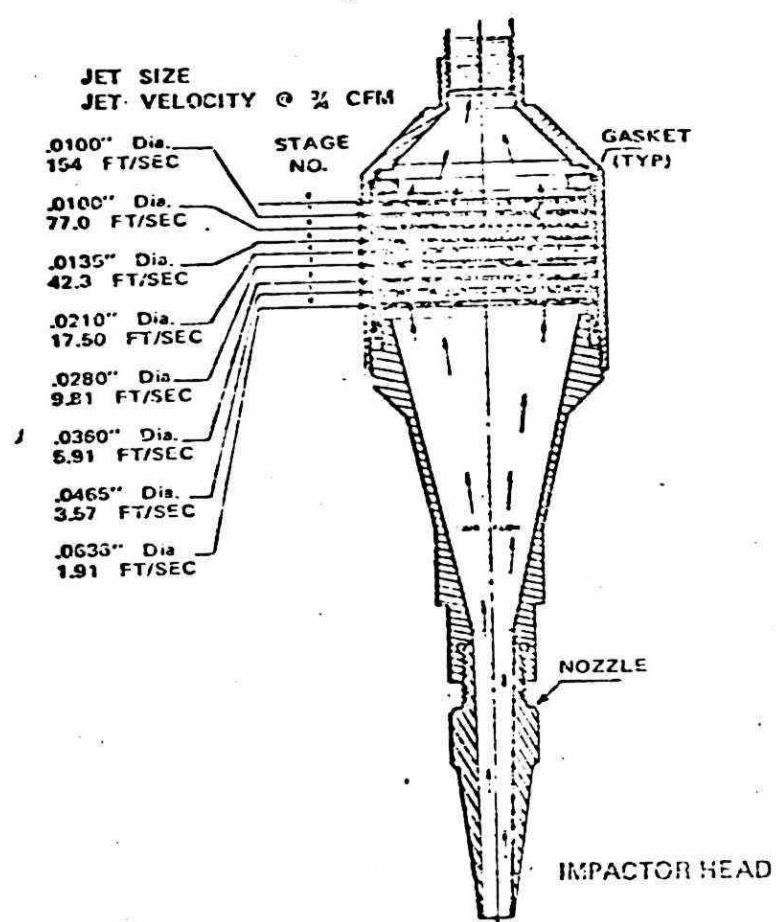


FIGURE 4 Andersen Cascade Impactor

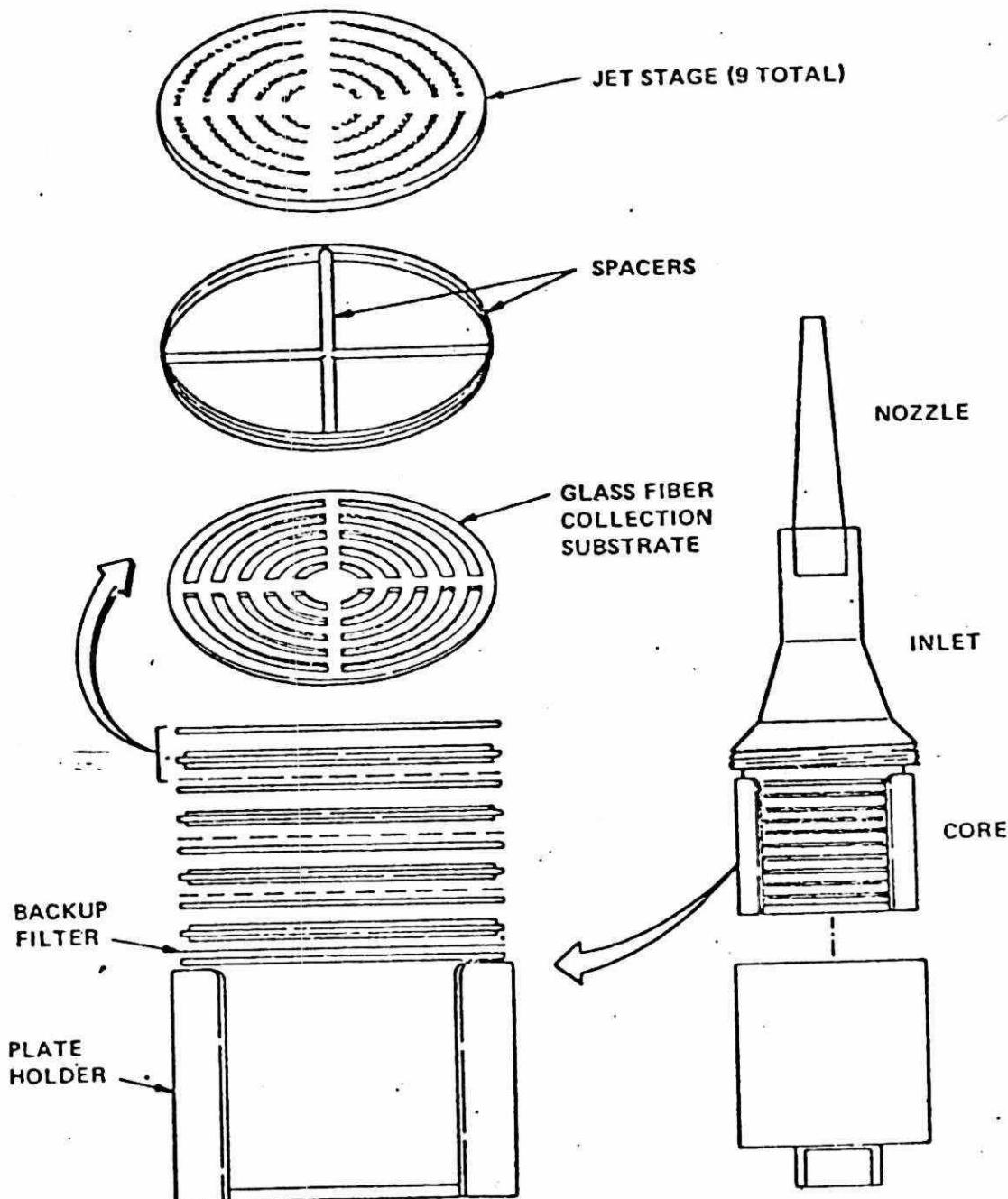


Fig. 5 'Andersen' Cascade Impactor
(Detailed)

INCO 1977 Superstack Tests, Acid, Particulate and Particle Sizing

TABLE 3. DETAILED SUMMARY OF ISOKINETIC RATES

Test Location	Test Date	Number of Readings	Number Sub-ISO	Number Super-ISO	Total Non-ISO	% Readings Within 100 ± 10% ISO.
INCO Superstack June, 1977	Acid #1 *	14	3	0	3	79
	June 7, 1977					
" "	Acid #2	22	5	1	6	73
	June 9, 1977					
" "	Particulate #1*	29	2	3	5	83
	June 6, 1977					
" "	Particulate #2*	28	3	1	4	86
	June 8, 1977					
" "	Particle Sizing*	9	2	0	2	78
	#1					
	June 8, 1977					

* Stack temperature adjusted by subtraction of 60°F due to improper calibration of temperature sensor.

(Continued) TABLE 3

DETAILED SUMMARY OF ISOKINETIC RATES FOR PARTICULATE TESTS

Test Location	Test Date	Number of Readings	Number Sub-ISO	Number Super-ISO	Total Non-ISO	% Readings Within 100 ± 10% ISO.
INCO Superstack	Particle	12	2	4	6	50
	Sizing #2					
	June 9, 1977					
" "	Particle	11	1	2	3	73
	Sizing #3					
	June 10, 1977.					

TABLE. 4. EMISSION RATES OF PARTICULATE

Source	Test# Date/76	Stack Gas Velocity (metric/sec)	Stack Gas Temp. C	Stack Gas Moisture (%)	Stack Gas Flow (DSCMM)	Emission Rate * Particulate		Particulate * Concentration		% ISOKINETIC
						(lb/hr)	(gm/sec)	(gr/SCF)	(gm/SCM)	
INCO SUPER STACK	Acid #1 June 7/77	19.5**	157	2.62	110,000	2612.	329.1	.0783	.179	91.89
	Acid #2 June 9/77	18.9	157	2.8	106,926	2787.0	351.2	.0861	.197	95.32
	Particulate #1, June 6/77	20.7**	174.	4.0	111,364	2508.0	316.0	.0744	.171	97.35
	Particulate #2, June 8/77	20.5**	170.	2.8	112,024	3362.0	423.7	.0991	.227	96.67

* Impinger Catch Not Included

** Stack Temperature Adjusted (see diagram on page).

TABLE: 5

EMISSION RATE OF SULFURIC ACID

SOURCE	TEST & DATE	STACK GAS VELOCITY metres/sec	STACK GAS TEMPERATURE 0C	STACK GAS FLOW DSCMM	EMISSION RATE grm/SCM	EMISSION RATE (gms/sec)
INCO Superstack June,	ACID #1 June 7, 1977	19.5	157.2 ^o	110,120	.0570	104.6
	ACID #2 June 9, 1977	18.9	157.2	106,930	.0582	103.8

* Includes Impingers

^o Stack Temperature Adjusted

TABLE 6: DISTRIBUTION OF ACID SULPHATES IN SAMPLING TRAIN

Source	Test	Date		Probe	Cyclone	Filter	Impingers	Total
INCO Superstack	Acid #1	June 7, 1977	Acid Sulfates (mg.)	64.9	-	11.1	7.6	83.6
			% of Total	77.63	-	13.28	9.1	100.00
"	Acid #2	June 9, 1977	Acid Sulfates (mg.)	29.9	-	10.5	45.6	86.00
			% of Total	34.77	-	12.21	53.02	100.00
"	Particulate #1	June 6, 1977	Acid Sulfates (mg.)	127.2	-	15.7	-*	142.9
			% of Total		-		-	
"	Particulate #2	June 9, 1977	Acid Sulfates (mg)	191.2	-	22.8	-*	214.0
			% of Total		-		-	

* Distilled Water Used in Impingers During Particulate Tests

TABLE 7. DISTRIBUTION OF PARTICULATE MATTER IN SAMPLING TRAIN

Source	Test	Date		Probe	Cyclone	Filter	Impingers*	Total
INCO Superstack	Acid #1	June 7, 1977	Particulate Matter (mg.)	151.9	0.00	111.00	178.8	441.7
			% of Total	34.39		25.13	40.48	100.0
"	Acid #2	June 9, 1977	Particulate Matter (mg.)	193.90	0.00	97.1	271.2	562.2
			% of Total	34.49		17.27	48.24	100.0
"	Particulate #1	June 6, 1977	Particulate Matter (mg.)	559.1	0.00	234.5	595.4	1389.0
			% of Total	40.26		16.86	42.87	100.00
"	Particulate #2	June 8, 1977	Particulate Matter	778.1	0.00	283.8	1239.6	2301.5
			% of Total	33.83		12.38	53.84	100.00

* Includes residue from fuming nitric acid wash.

TABLE 8. PARTICLE SIZING STAGE WEIGHTS

	Test #1 (mg) June 8, 1977	Test #2 (mg) June 8, 1977	Test #3 (mg) June 10, 1977.
Nozzle	1.9	2.2	45.5
Cyclone	15.4	5.2	10.5
Inlet*	265.4	341.5	5.6
Stage 0	14.1	12.2	29.9
Stage 1	14.0	10.8	11.6
Stage 2	13.0	13.4	13.0
Stage 3	14.1	12.2	12.0
Stage 4	13.8	11.9	11.3
Stage 5	13.0	9.2	10.9
Stage 6	13.0	10.8	11.5
Stage 7	9.3	10.2	10.9
Final Filter	8.7	11.3	8.3

* Inlet washings include those from all internal parts of the impactor, including spacing rings and backing plates. In Tests #1 and #2, where these weights were very large, only a nominal amount (see Test 3) was used in determining particle size distribution. These particles could have originated from any stage of the impactor and thus it was impossible to assign an ideal particle size cut-off diameter to them.

TABLE 9
PARTICLE SIZING TESTS
INCO SUPERSTACK - JUNE 1977

Test No. & Date	Nozzle Size Inches	Sample Time (mins)	Sample Volume std m ³	Overall Isokinetics	Theoretical Catch* mg	Actual Catch ^o mg
#1, June 8/77	1/8	45	.147	92.4	52.7	395.7(265.4)
#2, June 9/77	1/8	60	.289	105.7	69.43	450.96(341.5)
#3, June 10/77	3/16	36	.422	106.6	95.7	181 (5.6)

* Theoretical catch was derived by taking the maximum particulate concentration detected during acid and particulate tests (.227 grams per standard cubic metre) and multiplying this value by the sample volume.

o Numbers in brackets are the weights in milligrams of the inlet washing residue.

Note that:

- (1) Highest sample volume (Test #3) yielded lowest actual catch.
- (2) Abnormally high catches were reported for the first two tests, indicating that it is unlikely that the excess mass was a result of residues left in the equipment from previous programs.
- (3) A check of the original lab records verified the inlet wash weights reported.

TABLE 10 COMPARISON OF 1976 & 1977 PARTICLE SIZING DATA AND PROPOSED ALTERATION OF 1977 WEIGHTS.

Total Particulate Weight mg.	Percentage catch excluding glass fibre substrates	Concentration ¹ of Particulate mg/Std m ³
<u>1976 Data</u>		
Test 1	62.3	28.9 %
Test 2	86.9	26.5 %
Test 3	92.4	13.9 %
<u>Original 1977 Data</u>		
Test 1	395.7	71.4 %
Test 2	450.9	77.4 %
Test 3	181.	34.3 %
<u>Adjusted*</u> <u>1977 Data</u>		
Test 1	156.8	27.1 %
Test 2	143.5	29.0 %

*Weights were adjusted by lowering inlet weights for tests 1 and 2 by a factor of 10.

¹Maximum particulate concentration detected in 1977 during other sampling - 227. mg/SCM

APPENDIX 1: Sampling Data

INCO SUPERSTACK SOURCE TESTING

JUNE, 1977

TABLE 1 - ACID TEST #1, JUNE 7/77

STACK GAS PRESSURE : PBAR= 29.84 IN HG
 P STAT=-0.38 IN HG, -5.10 IN H2O
 P STACK= 28.67 IN HG

STACK GAS MOISTURE: WATER VOLUME IN IMPINGERS= 20.00 ML
 WATER VOLUME IN SILICA GEL= 9.40 ML
 MOISTURE VOLUME (TRAIN)= 1.39 SCF
 MOISTURE FRACTION,BWD = 0.09

STACK GAS COMPOSITION %CO2= 1.90 %O2= 20.00 %CO= 0.00
 %N2= 78.10 %SO2= 0.52

STACK GAS MOLECULAR WEIGHT: DRY MW-MW= 29.44
 WET MW-MW= 29.14
 EXC. AIR= 3234.15

TRAIN COMPONENTS SPECS: PITOT COEFFICIENT CV= 0.7950
 NOZZLE DIAMETER = 0.1875 INCHES
 METER CORR. FACTOR = 1.0000

STACK DIMENSIONS: DIAMETER= 540.000 INCHES, 0.000 INCHES
 AREA = 1590.431 SQFT

% ISOKINETIC							
POINT	DH H2O	DP H2O	TS °F	VS FT3	DMV FT3/MIN	DMQ	XI
1	0.25	0.90	300.0	61.5	2.02	0.40	85.25
2	0.26	0.96	320.0	64.3	2.29	0.46	94.80
3	0.26	0.96	320.0	64.3	2.21	0.44	91.49
4	0.25	0.92	330.0	63.4	2.25	0.45	95.75
5	0.25	0.92	330.0	63.4	4.41	0.44	93.84
6	0.26	0.96	340.0	65.2	4.47	0.45	93.70
7	0.26	0.94	300.0	64.1	4.37	0.44	92.00
8	0.26	0.92	310.0	62.6	4.60	0.46	96.64
9	0.26	0.96	300.0	63.5	4.30	0.43	87.86
10	0.26	0.95	290.0	63.1	4.22	0.42	85.65
11	0.26	0.96	310.0	63.9	4.53	0.45	93.16
12	0.26	0.98	310.0	64.6	4.47	0.45	90.99
13	0.29	1.00	310.0	65.2	4.63	0.46	93.30
14	0.29	1.00	310.0	65.2	4.57	0.46	92.09

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK, CITY:SUDBURY,
 TEST&DATE: ACID#1,JUNE7/77,

STACK GAS VELOCITY	STACK GAS TEMP.	STACK GAS MOIS.	STACK GAS FLOW	EMISSION RATE (IMPIGNERS EXCLUDED)	CONCENTRAT. (IMPIGNERS EXCLUDED)	EMISSION CONCENTRAT. (IMPIGNERS INCLUDED)	RATE GR/SCF	LB/HR	GR/SCF	GM/SEC	GM/SEC	GM/SEC
FPS 63.9	'F 315.0	% 2.6	1SCFM 3889760	LB/HR 2.612E+03	GR/SCF 7.833E-02	GR/SCF 4.388E+03	1.316E-01					
MPS 19.5	'C 157.2		1SCMM 110119.12	GM/SEC 3.291E+02	GM/SEC 1.792E-01	GM/SEC 552.843	GM/SEC 3.011E-01					

PARTIC EMISS. FRACT.: 4.39LB/TONS/H

ACID, EMISS. FRACT.: 0.83LB/TONS/H

ACID EMISSIONS

7.549E+02	2.264E-02	8.304E+02	2.491E-02
9.512E+01	5.161E-02	1.046E+02	5.699E-02

SATURATION MOISTURE: 592.91

RELATIVE HUMIDITY : 0.44

XISO : 91.89

SAMPLING TIME : 120.00

SAMPLE VOLUME : 51.91

TABLE 2 - ACID TEST #2, June 1977

STACK GAS PRESSURE : PBAR= 29.14 IN HG
 P STAT=-0.39 IN HG, -5.10 IN H2O
 P STACK= 28.77 IN HG

STACK GAS MOISTURE: WATER VOLUME IN IMPINGERS= 20.00 ML
 WATER VOLUME IN SILICA GEL= 12.00 ML
 MOISTURE VOLUME (TRAIN) = 1.52 SCF
 MOISTURE FRACTION,BW0 = 0.03

STACK GAS COMPOSITION %CO2= 1.90 %O2= 20.00 %CO= 0.00
 %N2= 78.10 %SO2= 0.52

STACK GAS MOLECULAR WEIGHT: DRY MW-MD 29.44
 WET MW-MW= 29.11
 %EXC. AIR= 3234.15

TRAIN COMPONENTS SPECS: PITOT COEFFICIENT CV= 0.7950
 NOZZLE DIAMETER = 0.1875 INCHES
 METER CORR. FACTOR = 1.0000

STACK DIMENSIONS: DIAMETER= 540.000 INCHES, 0.000 INCHES
 AREA = 1590.431 SQFT

% ISOKINETIC

POINT	DH H2O	DP H2O	TS °F	VS FT3	DGMV FT3/MIN	DGMQ	MI
1	0.28	0.96	340.0	65.1	1.30	0.26	54.69
2	0.24	0.96	320.0	64.3	1.28	0.26	53.17
3	0.26	0.92	320.0	62.9	2.12	0.42	89.96
4	0.28	0.92	320.0	62.9	2.50	0.50	106.09
5	0.28	0.94	320.0	63.6	2.35	0.47	98.65
6	0.28	0.94	320.0	63.6	2.45	0.49	102.85
7	0.28	0.90	310.0	61.8	5.60	0.56	119.36
8	0.25	0.88	320.0	61.5	3.60	0.36	78.89
9	0.28	0.90	320.0	62.2	2.05	0.41	87.95
10	0.30	0.88	320.0	61.5	2.35	0.47	101.97
11	0.30	0.88	320.0	61.5	2.23	0.45	96.76
12	0.30	0.86	310.0	60.4	2.35	0.47	102.48
13	0.30	0.88	320.0	61.5	2.35	0.47	101.97
14	0.30	0.88	320.0	61.5	2.40	0.48	104.14
15	0.29	0.90	320.0	62.2	2.38	0.48	102.11
16	0.29	0.90	320.0	62.2	2.32	0.46	99.54
17	0.29	0.88	310.0	61.1	2.30	0.46	99.15
18	0.29	0.88	300.0	60.7	2.30	0.46	98.51
19	0.29	0.88	300.0	60.7	2.30	0.46	98.51
20	0.29	0.86	300.0	60.0	2.50	0.50	108.31
21	0.29	0.88	300.0	60.7	2.15	0.43	92.08
22	0.30	0.88	300.0	60.7	2.35	0.47	100.65

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK,

CITY:SUDBURY,
 TEST&DATE: ACID#2,JUNE9/77,

STACK VELOCITY	STACK GAS TEMP.	STACK GAS MOIS.	STACK FLOW	EMISSION RATE (IMPINGERS EXCLUDED)	EMISSION CONCENTRATION (IMPINGERS INCLUDED)	EMISSION CONCENTRATION RATE
FPS. 62.0	'F 315.0	% 2.8	DSFCFM 3776376	LB/HR 2.787E+03	GR/SCF 8.609E-02	LB/HR 5.385E+03
MPS 18.9	'C 157.2		DSFCMM 106926.18	GM/SEC 0.512E+02	GM/SCM 1.970E-01	GM/SEC 678.463

PARTIC EMISS. FRT.: 5.38LB/TONG/H

ACID. EMISS. FRT.: 0.32LB/TONG/H

ACID EMISSIONS DATA

0.861E+02	1.175E-02	3.237E+02	7.500E-02
4.875E+01	2.775E-02	1.630E+02	3.875E-02

SATURATION MOISTURE: 540.54

%RELATIVE HUMIDITY : 64.48

T150 : 95.32

SAMPLING TIME : 120.00

SAMPLE VOLUME : 53.17

TABLE A3 PARTICULATE TEST #1 , JUNE 6/77

STACK GAS PRESSURE : PBAR= 29.10 IN HG
 P STAT=-0.38 IN HG,-5.10 IN H2O
 P STACK= 29.73 IN HG

STACK GAS MOISTURE: WATER VOLUME IN IMPINGERS= 63.00 ML
 WATER VOLUME IN SILICA GEL= 81.90 ML
 MOISTURE VOLUME (TRAIN) = 6.87 SCF
 MOISTURE FRACTION,BW0 = 0.04

STACK GAS COMPOSITION %CO2= 1.90 %O2= 20.00 %CO= 0.00
 %N2= 78.10 %SO2= 0.52

STACK GAS MOLECULAR WEIGHT: DRY MW-MD 29.44
 WET MW-MW= 28.98
 %EXC. AIR= 3234.15

TRAIN COMPONENTS SPECS: PITOT COEFFICIENT CV= 0.7950
 NOZZLE DIAMETER = 0.1875 INCHES
 METER CORR. FACTOR = 1.0000

STACK DIMENSIONS: DIAMETER= 540.000 INCHES, 0.000 INCHES
 AREA = 1590.431 SQFT

POINT	% ISOKINETIC						
	DH H2O	DP H2O	TS °F	VS FT3	DGMV FT3/MIN	DGMQ	NI
1	0.40	1.10	320.0	69.0	2.43	0.49	95.20
2	0.40	1.10	320.0	69.0	2.77	0.55	108.52
3	0.40	1.10	320.0	69.0	2.70	0.54	105.78
4	0.40	1.10	340.0	69.9	2.82	0.56	111.89
5	0.40	1.10	340.0	69.9	2.93	0.59	116.26
6	0.39	1.20	360.0	67.4	2.37	0.47	99.85
7	0.39	1.00	360.0	67.4	2.58	0.52	108.70
8	0.39	0.96	360.0	66.1	7.82	0.52	112.08
9	0.36	0.96	360.0	66.1	7.10	0.47	101.76
10	0.28	0.96	360.0	66.1	6.98	0.47	100.02
11	0.28	0.96	360.0	66.1	6.88	0.46	99.58
12	0.28	1.00	340.0	66.6	6.72	0.45	93.19
13	0.26	1.00	340.0	66.6	6.71	0.45	93.04
14	0.25	0.96	340.0	65.3	7.21	0.48	102.04
15	0.25	1.06	330.0	68.2	6.17	0.41	82.58
16	0.25	1.06	330.0	68.2	6.68	0.45	89.40
17	0.27	1.08	320.0	68.4	7.02	0.47	92.49
18	0.29	1.00	340.0	66.6	6.73	0.45	93.33
19	0.27	0.98	340.0	66.0	6.75	0.45	94.55
20	0.27	1.06	330.0	68.2	6.95	0.46	93.02
21	0.28	1.10	350.0	70.3	6.80	0.45	90.47
22	0.26	0.98	340.0	66.0	6.70	0.45	93.85
23	0.26	1.00	330.0	66.2	6.72	0.45	92.60
24	0.27	1.06	340.0	68.6	6.78	0.45	91.32
25	0.28	1.06	360.0	69.4	7.02	0.47	95.73
26	0.28	1.06	360.0	69.4	6.63	0.44	90.41
27	0.26	1.03	380.0	69.3	6.55	0.44	91.70
28	0.26	1.10	380.0	71.6	6.80	0.45	92.12
29	0.28	1.10	380.0	71.6	6.85	0.46	92.81

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK, CITY: SUDBURY,
 TEST&DATE: PART#1, JUNE 6/77,

STACK GAS VELOCITY	STACK GAS TEMP.	STACK GAS MOIS.	STACK GAS FLOW	EMISSION RATE (IMPINGERS EXCLUDED)	EMISSION CONCENTRAT. RATE (IMPINGERS INCLUDED)		
FPS 68.0	°F 345.9	% 4.0	DSFCFM 3933744	LB/HR 2.507E+03	GR/SCF 7.436E-02	LB/HR 4.389E+03	GR/SCF 1.793E-01
MPS 20.7	°C 174.4		DSFCMM 111364.31	GM/SEC 3.159E+02	GM/SCM 1.701E-01	GM/SEC 553.034	GM/SCM 3.573E-01

PARTIC EMISS. FACT.: 4.39LB/TONS/H

SATURATION MOISTURE: 904.67
 %RELATIVE HUMIDITY : 0.44
 %ISO : 97.35
 SAMPLING TIME : 365.00
 SAMPLE VOLUME : 164.66

TABLE A4 PARTICULATE TEST # 2, JUNE '77

STACK GAS PRESSURE : PBAR= .38.92 IN HG
 P STAT=-0.38 IN HG, -5.10 IN H2O
 P STACK= 28.55 IN HG

STACK GAS MOISTURE: WATER VOLUME IN IMPINGERS= 48.00 ML
 WATER VOLUME IN SILICA GEL= 52.90 ML
 MOISTURE VOLUME (TRAIN) = 4.78 SCF
 MOISTURE FRACTION,BW0 = 0.03

STACK GAS COMPOSITION %CO2= 1.90 %O2= 20.00 %CO= 0.00
 %N2= 78.10 %SO2= 0.52

STACK GAS MOLECULAR WEIGHT: DRY MW-MW= 29.44
 WET MW-MW= 29.12
 %EXC. AIR= 3234.15

TRAIN COMPONENTS Specs: PITOT COEFFICIENT CV= 0.7950
 NOZZLE DIAMETER = 0.1875 INCHES
 METER CORR. FACTOR = 1.0000

STACK DIMENSIONS: DIAMETER= 540.000 INCHES, 0.000 INCHES
 AREA = 1590.431 SQFT

% ISOKINETIC

POINT	DH H2O	DP H2O	TS 'F	VS FT3	DGMV FT3/MIN	DGMO	%I
1	0.30	1.00	340.0	66.7	2.60	0.52	106.77
2	0.28	1.00	340.0	66.7	2.35	0.47	96.50
3	0.30	1.06	330.0	68.2	2.37	0.47	93.93
4	0.31	1.10	320.0	69.5	2.40	0.48	93.38
5	0.30	1.06	330.0	68.2	2.46	0.49	97.50
6	0.31	1.06	320.0	67.8	2.44	0.49	96.10
7	0.32	1.10	310.0	68.6	2.30	0.49	93.47
8	0.31	1.06	330.0	68.2	2.33	0.49	96.84
9	0.31	1.00	340.0	66.7	6.95	0.46	95.13
10	0.29	1.00	360.0	67.5	7.50	0.50	103.93
11	0.31	1.06	350.0	69.1	7.20	0.48	96.32
12	0.31	1.06	350.0	69.1	6.72	0.45	89.90
13	0.29	0.96	350.0	65.7	6.95	0.46	97.70
14	0.30	1.00	360.0	67.5	7.15	0.48	99.08
15	0.33	1.06	340.0	68.6	7.10	0.47	94.40
16	0.33	1.06	340.0	68.6	7.25	0.48	96.40
17	0.33	1.06	340.0	68.6	7.25	0.48	96.40
18	0.31	1.03	350.0	68.1	8.20	0.55	111.29
19	0.30	1.06	340.0	68.6	5.91	0.39	78.57
20	0.31	1.06	340.0	68.6	7.19	0.48	95.59
21	0.30	0.98	340.0	66.0	7.15	0.48	98.86
22	0.29	0.98	350.0	66.4	5.95	0.40	82.78
23	0.28	0.94	330.0	64.2	7.80	0.52	109.42
24	0.29	0.96	350.0	65.7	7.00	0.47	98.40
25	0.31	1.00	330.0	66.3	7.00	0.47	95.22
26	0.31	1.00	330.0	66.3	7.20	0.48	97.94
27	0.30	0.96	350.0	65.7	6.80	0.45	95.59
28	0.32	1.00	310.0	65.4	7.40	0.49	99.38

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK, CITY:SUDBURY,
 TEST&DATE: PART#2, JUNE8/77,

STACK GAS VELOCITY	STACK GAS TEMP.	STACK GAS MOIS.	STACK GAS FLOW	EMISSION RATE (IMPIGNERS EXCLUDED)	CONCENTRAT. (IMPIGNERS EXCLUDED)	EMISSION RATE (IMPIGNERS INCLUDED)	
FPS 67.4	'F 338.6	% 2.8	DSFCFM 3957051	LB/HR 3.366E+03	GR/SCF 9.920E-02	LB/HR 7.291E+03	GR/SCF 2.150E-01
MPS 20.5	'C 170.3		DSFCMM 112024.11	GM/SEC 4.241E+02	GM/CCM 2.270E-01	GM/SEC 918.614	GM/SCF 4.913E-01

PARTIC EMISS. FACT.: 7.29LB/TONS/H

SATURATION MOISTURE: 826.19
 %RELATIVE HUMIDITY : 0.34
 %ISO : 96.67
 SAMPLING TIME : 360.00
 SAMPLE VOLUME : 165.34

TABLE A5 - PARTICLE SIZING TEST 1

STACK GAS PRESSURE

P BAR = 29.04 IN HG
 P STAT = 0.3750 IN HG, 5.1000 IN H2O
 P STACK= 29.4150 IN HG

STACK GAS MOISTURE

WATER VOLUME IN IMPINGERS = 5.0000 ML
 WATER VOLUME IN SILICAGEL = 2.0000 ML
 MOISTURE VOLUME (TRAIN) = 0.3318 CUFT
 TOTAL GAS VOLUME (TRAIN) = 8.5341 CUFT
 MOISTURE FRACTION,BWO = 0.0389

STACK GAS COMPOSITION

%CO2= 1.90 %O2= 20.00 %CO= 0.00 %N2= 78.10 %SO2 0.52

STACK GAS MOLECULAR WEIGHT

DRY MW,MID= 29.4368
 WET MW,MW= 28.9921
 %EXC. AIR= 3234.1527

TRAIN COMPONENTS SPECS

PITOT COEFFICIENT CV= 0.8940
 NOZZLE DIAMETER = 0.1250 INCHES
 METER CORR.FACTOR = 1.0000

STACK DIMENSIONS

DIAMETER= 540.0000 INCHES
 AREA = 1590.4313 SQFT

EMISSION PARAMETERS

FLOWRATE = 220656678.2420 SCFH 3677611.3040 SCFM
 PARTICULATE CONCENTRATIONS= 1.0637E-04 LB/ CUFT
 = 7.4448E-01 GR/ CUFT
 = 4.8243E-02 GM/ CUFT

% ISOKINETIC

POINT	DH H2O	DP H2O	TS 'F	VS FT/SEC	DGMV FT3	DGMD FT3/LIN	%I
1	0.04	0.70	300.0	60.4	0.92	0.18	87.84
2	0.04	0.70	320.0	61.1	0.98	0.20	94.79
3	0.04	0.70	320.0	61.1	1.00	0.20	96.72
4	0.04	0.66	340.0	60.1	0.90	0.18	90.79
5	0.04	0.66	340.0	60.1	0.80	0.16	80.70
6	0.04	0.70	350.0	62.3	1.05	0.21	103.49
7	0.04	0.70	360.0	62.7	0.95	0.19	94.21
8	0.04	0.70	360.0	62.7	0.92	0.18	91.24
9	0.04	0.70	360.0	62.7	0.93	0.19	92.23

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK,

CITY: SUDBURY,
 TEST DATE: SUPER STACK,

STACK GAS VELOCITY FPS	STACK GAS TEMP 'F	STACK GAS MOISTURE %	STACK GAS FLOW DSCFM	EMISSION RATE (IMP. EXC.) LB/HR	PERCENT ISOKINETIC	TOTAL VOLUME SCF	TIME MIN
61.5	338.9	3.9	3677611	2.35E+04 2.96E+03 GM/SEC	92.4	8.2	45.0

COMPONENT DISTRIBUTION IN SAMPLING TRAIN

	PROBE	CYCLONE	FILTER	IMPIGNERS	TOTAL
PARTICLE SIZING (MG)	282.7000	0.0000	113.0000	0.0000	395.7000
% OF TOTAL PARTICLE	71.4430	0.0000	28.5569	0.0000	100.0000

TABLE A6 - PARTICLE SIZING TEST 2

STACK GAS PRESSURE

P BAR = 29.14 IN HG
 P STAT = 0.3750 IN HG, 5.1000 IN H2O
 P STACK= 29.5150 IN HG

STACK GAS MOISTURE

WATER VOLUME IN IMPINGERS = 6.0000 ML
 WATER VOLUME IN SILICAGEL = 3.0000 ML
 MOISTURE VOLUME (TRAIN) = 0.4266 CUFT
 TOTAL GAS VOLUME (TRAIN) = 11.2482 CUFT
 MOISTURE FRACTION,BWD = 0.0379

STACK GAS COMPOSITION

%CO2= 1.90 %O2= 20.00 %CO= 0.00 %N2= 78.10 %SO2 0.52

STACK GAS MOLECULAR WEIGHT

DRY MW,MW= 29.4368
 WET MW,MW= 29.0030
 %EXC. AIR= 3234.1527

TRAIN COMPONENTS SPECS

PITOT COEFFICIENT CV= 0.8940
 NOZZLE DIAMETER = 0.1250 INCHES
 METER CORR.FACTOR = 1.0000

STACK DIMENSIONS

DIAMETER= 540.0000 INCHES
 AREA = 1590.4313 SQFT

EMISSION PARAMETERS

FLOWRATE = 190927644.7270 SCFH 3182127.4121 SCFM
 PARTICULATE CONCENTRATIONS, 9.1875E-05 LB/CUFT
 = 6.4300E-01 GR/CUFT
 = 4.1667E-02 GM/CUFT

% ISOKINETIC

POINT	DH H2O	DP H2O	TS °F	VS FT/SEC	DGMV FT3	DGMQ FT3/LIN	%I
1	0.06	0.50	300.0	50.9	1.20	0.24	135.70
2	0.06	0.50	320.0	51.6	1.15	0.23	131.74
3	0.04	0.52	320.0	52.6	0.95	0.19	106.71
4	0.04	0.52	320.0	52.6	0.98	0.20	110.08
5	0.04	0.52	320.0	52.6	0.82	0.16	92.11
6	0.04	0.52	320.0	52.6	0.80	0.16	89.86
7	0.04	0.52	320.0	52.6	0.91	0.18	102.22
8	0.04	0.50	320.0	51.6	0.94	0.19	107.68
9	0.04	0.50	320.0	51.6	0.93	0.19	106.53
10	0.04	0.50	320.0	51.6	1.02	0.20	116.84
11	0.04	0.46	320.0	49.5	0.62	0.12	74.05
12	0.04	0.46	320.0	49.5	0.79	0.16	94.35

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK,

CITY: SUDBURY,
 TEST&DATE: SUPER STACK,

STACK GAS VELOCITY FPS	STACK GAS TEMP 'F	STACK GAS MOISTURE %	STACK GAS FLOW DSCFM	EMISSION RATE (IMP. EXC.) LB/HR	PERCENT ISOKINETIC	TOTAL VOLUME SCF	TIME MIN
51.6	318.3	3.8	3182127	1.75E+04 2.21E+03GM/SEC	105.7	10.8	60.0

COMPONENT DISTRIBUTION IN SAMPLING TRAIN

	PROBE	CYCLONE	FILTER	IMPIGNERS	TOTAL
PARTICULATE (MG)	7.4000	341.5000	102.0000	0.0000	450.9000
% OF TOTAL PARTICULA	1.6412	75.7374	22.6214	0.0000	100.0000

TABLE A7 - PARTICLE SIZING TEST 3

STACK GAS PRESSURE

P BAR = 29.36 IN HG
 P STAT = 0.3750 IN HG, 5.1000 IN H2O
 P STACK= 29.7350 IN HG

STACK GAS MOISTURE

WATER VOLUME IN IMPINGERS = 6.0000 ML
 WATER VOLUME IN SILICAGEL = 2.0000 ML
 MOISTURE VOLUME (TRAIN) = 0.3792 CUFT
 TOTAL GAS VOLUME (TRAIN) = 15.3139 CUFT
 MOISTURE FRACTION,BWO = 0.0248

STACK GAS COMPOSITION

%CO2= 1.90 %O2= 20.00 %CO= 0.00 %N2= 78.10 %SO2 0.52

STACK GAS MOLECULAR WEIGHT

DRY MW,MD= 29.4368
 WET MW,MW= 29.1536
 %EXC. AIR= 3234.1527

TRAIN COMPONENTS SPECS

PITOT COEFFICIENT CV= 0.8940
 NOZZLE DIAMETER = 0.1825 INCHES
 METER CORR.FACTOR = 1.0000

STACK DIMENSIONS

DIAMETER= 540.0000 INCHES
 AREA = 1590.4313 SQFT

EMISSION PARAMETERS

FLOWRATE = 204220646.1920 SCFH 3403677.4365 SCFM
 PARTICULATE CONCENTRATIONS= 2.6723E-05 LB/CUFT
 = 1.8703E-01 GR/CUFT
 = 1.2119E-02 GM/CUFT

% ISOKINETIC

POINT	DH H2O	DP H2O	TS °F	VS FT/SEC	DGMV FT3	DGMO FT3/LIN	XI
1	0.25	0.56	335.0	54.8	2.58	0.43	109.49
2	0.26	0.58	335.0	55.7	1.28	0.43	106.75
3	0.26	0.57	335.0	55.3	1.32	0.44	111.05
4	0.26	0.57	340.0	55.4	1.27	0.42	107.18
5	0.26	0.57	340.0	55.4	1.27	0.42	107.18
6	0.26	0.56	340.0	54.9	1.23	0.41	104.73
7	0.26	0.56	340.0	54.9	1.23	0.41	104.73
8	0.24	0.56	330.0	54.6	1.24	0.41	104.91
9	0.24	0.58	335.0	55.7	1.23	0.41	102.58
10	0.24	0.58	335.0	55.7	0.95	0.32	79.23
11	0.24	0.58	335.0	55.7	1.61	0.54	134.27

SUMMARY OF EMISSION TESTS

COMPANY: INCO,
 LOCATION: SUPER STACK,

CITY: SUDBURY,
 TEST&DATE: SUPER STACK,

STACK GAS VELOCITY FPS	STACK GAS TEMP °F	STACK GAS MOISTURE %	STACK GAS FLOW DSCFM	EMISSION RATE (IMP. EXC.) LB/HR	PERCENT ISOKINETIC	TOTAL VOLUME SCF	TIME MIN
55.3	336.4	2.5	3403677	5.46E+03 6.88E+02GM/SEC	106.6	14.9	36.0

COMPONENT DISTRIBUTION IN SAMPLING TRAIN

	PROBE	CYCLONE	FILTER	IMPIGNERS	TOTAL
PARTICULATE % OF TOTAL PARTICULA	(MG)	61.6000 34.0031	0.0000 0.0000	119.4000 65.9668	0.0000 0.0000
					181.0000 100.0000

APPENDIX 2

ANALYTICAL PROCEDURES AND RESULTS

INCO SUPERSTACK - JUNE, 1977

ANALYSES OF SAMPLES OBTAINED FROM
INCO SUPER STACK
JUNE/JULY 1977

The sampling and stack testing were carried out in a similar manner to that previously described for 1976. The tests were again divided into three groups; a) Acid Tests b) Particulate and c) Size Fractionation, as follows:

A. Acid Tests

Two acid tests were carried out and the following samples received:

- 1) Front IPA Washing
- 2) Filter
- 3) 1st, 2nd and 3rd Impinger
- 4) Acid Wash

These samples were treated as follows:

1) Front IPA Washing

These samples were filtered, the residue dried and weighed (Table III A & B). The IPA solution and an aqueous extract of the residue were analysed for sulphate and reported in Table I.

2) Probe Filter

This filter contains a mixture of both acid and non acid sulphates and was conditioned at 50% humidity and weighed to constant weight. Results are reported in Table II A. Blanks #3-5 were also carried through the same operation. Blank differences are reported, but reported loading not corrected for blanks.

The conditioned filter was extracted with IPA to remove acid sulphates. The dried residue was then extracted with water. Both extracts were analysed for sulphates. Results reported in Table I.

3) Impinger Solutions

These solutions (3) were treated in a similar manner to the Front IPA Washings. Sulphate results reported in Table I.

4) Acid Wash

A 100 ml. aliquot was taken and analysed for As and SO₄. The remainder of the solution was taken to dryness to

determine total residue and the residue dissolved in acid and metals determined (Table III A & B).

Metals were not requested on this series of tests, however, for additional information, the samples were analysed and the results reported in Tables III A & B.

B. Particulate Test

Two particulate tests were carried out on the INCO stack. These were separated and analysed in a manner similar to the acid tests with the addition of a comprehensive survey for metals. The prepared samples were analysed for Cd, Cr, Cu, Pb, Mn, Zn, Al, Bi, Si, Ca, Co, Fe, K, Mg, Ni, V, Na, As. The sample preparations were as follows:

1) Front IPA Washings

The washings were treated in an identical manner to the acid test samples and residue weight, acid and non acid sulphates determined. Results are given in Table I and Table IV A & B.

Metals were determined on the IPA extract, aqueous extract of residue and acid extract of residue. Results reported in Table IV A & B.

2) Filter

The probe filters were conditioned and residue weight determined (Table II B). The filter was first extracted with IPA and metals and sulphates determined on the extract. An aqueous extract of the filter was then made and the above analysis repeated. The remaining residue was then acid extracted with 1:1:1 HF/NO₃ and the metals determined. Results are given in Table I and Table IV A & B.

3) Impinger Solution

This solution was divided into two portions, one portion evaporated to dryness to determine residue weight and the residue acid digested with HCl/HNO₃ for metal determination (Tables IV A & B). Sulphate and arsenic were determined on the remaining portion after excess IPA was removed in a rotary evaporator (Table I and Table IV A & B).

4) Acid Wash

This solution was treated in the same manner as the acid wash for the acid test. Results reported in Table IV A & B.

C. Size Fractionation Tests

Three tests were performed using pre-conditioned weighed filters. Each test run consisted of eight fraction filters and a backup filter. Loaded filters were conditioned at 50% humidity and weighed to constant weight. Results are reported in Tables II D, E and F. Two sets of unexposed filters were also conditioned and reweighed. Results of these weighings are given in Tables II C and G. Loaded weights in Tables D, E and F are not corrected for weight changes in blanks.

Two sets of filters III and IV were acid extracted and analysed for metals. Results are given in Table V A & B. Set #II was extracted with water and the aqueous extract analysed for sulphate. Results reported in Table VI.

The Probe, Cyclone and Inlet IPA Wash for these three runs were also analysed for metals and total residue determined. Results are given in Tables VII A, B and C.

One spot from each filter stage of the fractionation was submitted to the Physical Section for electron microscopic evaluation. The results obtained will be reported by that Section.

Conclusions

Due to sample limitations, several analyses requested could not be undertaken. Where digestion called for HF/HNO₃ attack silica or arsenic could not be determined. Acid attack on residue precludes determination of Sn. Silica could only be determined on soluble portions due to the need for fusion.

These results should be compared with those obtained for 1976. Large variations in metal concentrations have been observed.

ABF/vc
November 10, 1977

SULPHATE LEVEL mg SO₄

Sample Description	A ACID TESTS		PARTICULATE TESTS	
	Test 1	Test 2	Test 1	Test 2
<u>FRONT IPA WASH</u>				
a) IPA Extract	64.9	29.9	127.2	191.2
b) Aqueous Extract	44.1	62.5	268.0	285.0
<u>FILTER</u>				
a) IPA Extract	11.1	10.5	15.7	22.8
b) Aqueous Extract	35.8	28.6	56.2	59.1
<u>IMPIINGER 1</u>				
a) IPA Extract	4.2	1.7	-	-
b) Aqueous Extract	84.1	13.8	-	-
<u>IMPIINGER 2</u>				
a) IPA Extract	2.2	1.2	-	-
b) Aqueous Extract	20.2	5.7	-	-
<u>IMPIINGER 3</u>				
a) IPA Extract	1.2	42.7	-	-
b) Aqueous Extract	4.9	1.8	-	-
Total Sulphate Impinger	116.8	66.9	95	56.3

TABLE I

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SUDBURY ENVIRONMENTAL STUDY

Inco Stack Test Results - June, 1977

TABLE II A-C

ACID TEST FILTER WEIGHTS

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg.)
Acid Test #1	0.9267	1.0377		111.0
#2	0.9225	1.0196		97.1
#3	0.9212		0.9219	+ 0.7
#4	0.9174		0.9173	- 0.1
#5	0.9245		0.9239	- 0.6

A
PARTICULATE TEST FILTER WEIGHTS

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg.)
Part. Test #1	0.9349	1.1694		234.5
#2	0.9249	1.2087		283.8
#3	0.9302		0.9303	+ 0.1
#4	0.9265		0.9258	- 0.7
#5	0.9284		0.9279	- 1.4

B
SIZE FRACTIONATION WEIGHTS (UNEXPOSED)

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg.)
Size #1-Filter #1	0.1522		0.1529	+ 0.7
#1 #2	0.1400		0.1407	+ 0.7
#1 #3	0.1515		0.1520	+ 0.5
#1 #4	0.1401		0.1403	+ 0.2
#1 #5	0.1440		0.1445	+ 0.5
#1 #6	0.1389		0.1393	+ 0.4
#1 #7	0.1433		0.1436	+ 0.3
#1 #8	0.1313		0.1318	+ 0.5
#1 F	0.1667		0.1670	+ 0.3

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg)
Size #2-Filter #1	0.1536	0.1677		14.1
#2 #2	0.1416	0.1556		14.0
#2 #3	0.1517	0.1647		13.0
#2 #4	0.1420	0.1561		14.1
#2 #5	0.1544	0.1682		13.8
#2 #6	0.1401	0.1531		13.0
#2 #7	0.1558	0.1688		13.0
#2 #8	0.1449	0.1542		9.3
#2 F	0.1639	0.1726		8.7

D

SIZE FRACTIONATION WEIGHTS (EXPOSED)

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg)
Size #3-Filter #1	0.1525	0.1647		12.2
#3 #2	0.1317	0.1425		10.8
#3 #3	0.1529	0.1663		13.4
#3 #4	0.1395	0.1517		12.2
#3 #5	0.1442	0.1561		11.9
#3 #6	0.1399	0.1491		9.2
#3 #7	0.1556	0.1664		10.8
#3 #8	0.1452	0.1554		10.2
#3 F	0.1663	0.1776		11.3

E

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg)
Size #4 -Filter #1	0.1565	0.1684		29.9
#1 #2	0.1548	0.1664		11.6
#1 #3	0.1566	0.1696		13.0
#4 #4	0.1427	0.1547		12.0
#4 #5	0.1407	0.1520		11.3
#4 #6	0.1309	0.1418		10.9
#4 #7	0.1510	0.1625		11.5
#4 #8	0.1402	0.1511		10.9
#4 F	0.1648	0.1731		8.3

F Internal Residue Weight:

SIZE FRACTIONATION WEIGHTS (UNEXPOSED)

Sample	Blank Weight (Before Tests) (grams)	Loaded Weight (grams)	Blank Weight (After Tests) (grams)	Weight Difference (mg)
Size #5 -Filter #1	0.1490		0.1500	+ 1.0
#5 #2	0.1400		0.1408	+ 0.8
#5 #3	0.1517		0.1519	+ 0.2
#5 #4	0.1400		0.1406	+ 0.6
#5 #5	0.1594		0.1604	+ 1.0
#5 #6	0.1364		0.1372	+ 0.8
#5 #7	0.1518		0.1523	+ 0.5
#5 #8	0.1395		0.1403	+ 0.8
#5 F	0.1616		0.1623	+ 0.7

TESTS AT I (June 7/77)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V	Na	As (ppm)	Total residue (g)
1.1 TGA WASH AT(1)-1																			
Hg sol extract	95.0	22.8	2665.4	49.4	18.5	1018.1	277.7	431.9	7218.9	61.7	55.5	11044.3	18.5	401.1	660.2	86.4	259.1	35004.0	
H ₂ O sol extract	72.0	7.5	5000.0	170.0	20.0	725.0	50.0	<25.0	<50.0	530.0	85.0	4800.0	630.0	305.0	2485.0	<7.5	1000.0	155.6	
Residue	6.5	130.5	2722.5	387.5	18.0	140.0	310.0	125.0	2200.0	195.0	97.5	16575.0	95.0	550.0	3825.0	120.0	N.D.	1485.0	
1.2 TGA WASH AT(1)-2																			
Hg sol extract	13.0	8.5	*	*	35.0	55.0	<25.0	*	*	*	*	<7.5	<5.0	*	*	<7.5	7.5	12555.6	
H ₂ O sol extract	2.4	<6.0	*	*	<6.0	36.7	<25.0	263.2	2325.6	42.8	<18.0	134.6	30.6	.2	30.6	<7.5	*	3767.2	
Residue	.75	<2.5	<2.5	<7.5	<1.25	<7.5	<25.0	<25.0	200.0	77.5	<5.0	7.5	17.5	3.5	<7.5	<7.5	N.D.	715.	
1.3 TGA WASH AT(1)-3																			
Hg sol extract	13.0	6.5	<5.0	<15.0	<5.0	<15.0	<25.0	315.0	125.0	<15.0	<15.0	<15.0	<5.0	110.0	<7.5	7.5	11145.0		
H ₂ O sol extract	<1.3	<6.5	6.5	<15.0	<6.5	20.0	<25.0	<25.0	3617.6	<15.0	<15.0	<15.0	12.9	<6.5	<6.5	<19.5	96.9		
Residue	<.75	<2.5	<2.5	<7.5	<1.25	<7.5	<25.0	<25.0	<50.0	12.5	<5.0	10.0	7.5	2.5	<7.5	<7.5	N.D.	177.5	
1.4 TGA WASH AT(1)-4																			
Hg sol extract	12.0	8.0	<5.0	<15.0	<5.0	<15.0	<25.0	355.0	400.0	<15.0	<15.0	<15.0	<5.0	125.0	<15.0	7.5	275.0		
H ₂ O sol extract	<1.3	<6.5	<6.5	<15.0	<6.5	<15.0	<25.0	<25.0	634.0	<15.0	<15.0	<15.0	6.3	<6.5	<6.5	<19.5	38.0		
Residue	<.75	<2.5	<2.5	<7.5	<1.25	<7.5	<25.0	<25.0	<50.0	10.0	<5.0	10.0	10.0	<2.5	<7.5	<7.5	N.D.	60.0	
1.5 TGA WASH AT(1)-5	1.62	330.1	31.5	<10.0	3.6	19.5	2235.1	<33.0	487.3	68.2	<6.5	178.7	45.5	16.9	39.0	<10.0	N.D.	22380.3	
1.6 TIPS AT-F-1																			
Hg sol extract	<1.0	6.0	50.0	<15.0	<5.0	120.0	25.0	<25.0	N.D.	N.D.	<15.0	110.0	N.D.	N.D.	<25.0	<15.0	N.D.	9900.0	
H ₂ O sol extract	163.9	<11.0	1298.0	242.0	<11.0	638.0	110.0	<55.0	N.D.	N.D.	<33.0	847.0	N.D.	N.D.	330.0	<33.0	N.D.	5768.9	
Residue	4.5	2.3	177.5	2636.0	1.5	52.5	250.0	243.3	N.D.	N.D.	7.5	920.0	N.D.	N.D.	230.0	12.5	N.D.	***	

***HF attack No As

Total Fe ug 340

Add water 26% 29% 7

TABLE III A

Total Imp with acid wash .002 mg

Probe .36 mg

Filter .016 mg

LID TEST II (June 9/77)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V	Na	As (ppm)	Total Particulate Wt. (g)
ACID WASH AT(2)-1																			
HFA sol extract	21.8	176.0	299.1	<19.2	6.4	403.2	<32.0	<32.0	4800.0	44.8	<19.2	556.8	32.0	102.4	217.6	<19.2	140.8	4323.6	
HFA sol extract	78.0	54.0	4380	175.0	30.0	560.0	180.0	25.0	<500.0	530.0	125.0	9450.0	570.0	420.0	3350.0	<20.0	110.0	411.1	
Residue	7.0	300.0	1440.0	267.5	33.0	120.0	392.5	187.5	2900.0	192.5	147.5	18125.0	127.5	532.5	3750.0	142.5	N.D.	3817.5	0.1939
ACID WASH AT(2)-2																			
HFA sol extract	15.0	6.5	<5.0	35.0	<5.0	<15.0	<25.0	450.0	30500.0	<15.0	55.0	<15.0	<5.0	<5.0	135.0	<15.	<15	1955.6	
HFA sol extract	<1.2	<6.2	29.7	<18.5	<6.2	30.9	<30.9	<30.9	20146.0	24.7	<18.5	142.1	24.7	18.5	<30.9	<18.5	191.6	2987.0	
Residue	<.75	<2.5	<2.5	<7.5	<1.25	<7.5	<25.0	<25.0	150.0	15.0	<5.0	10.0	7.5	6.5	<7.5	<7.5	N.D.	1547.5	0.0181
ACID WASH AT(2)-3																			
HFA sol extract	9.5	<5.0	<5.0	<15.0	<5.0	<15.0	<25.0	375.0	1350.0	15.0	25.0	20.0	<5.0	<5.0	100.0	<15.0	<15.0	220.0	
HFA sol extract	<1.2	<6.2	<6.2	<18.5	<6.2	<18.5	<30.9	<30.9	22000.0	18.5	<18.5	<18.5	<6.2	37.1	<30.9	<18.5	61.8	1284.1	
Residue	<.75	<2.5	2.5	<7.5	<1.25	<7.5	<25.0	<25.0	75.0	17.5	<5.0	12.5	12.5	13.5	<7.5	<7.5	N.D.	417.5	0.0031
ACID WASH AT(2)-4																			
HFA sol extract	14.0	6.5	<5.0	<15.0	<5.0	<15.0	<25.0	515.0	<500.0	<15.0	50.0	<15.0	10.0	<5.0	160.0	<15.0	<15.0	2777.8	
HFA sol extract	<1.1	<5.4	<10.2	<16.1	<5.4	<16.1	<26.8	1072.0	26.8	<16.1	5.4	<16.1	5.4	<5.4	<26.8	<16.1	42.9	744.4	
Residue	<.75	<2.5	<2.5	<7.5	<1.25	<7.5	<25.0	<25.0	<50.0	15.0	<5.0	7.5	12.5	2.75	<7.5	<7.5	N.D.	120.0	0.0015
ACID WASH AT(2)-5																			
FILTERS AT-E-2	12.2	424.2	37.2	9.9	4.0	75.6	2426.9	<33.0	394.6	184.2	<6.5	203.9	52.6	24.7	39.5	<10.0	N.D.	16064.1	0.0485
HFA sol extract	3.5	<5.0	61.5	<15.0	<5.0	65.0	<25.0	<25.0	N.D.	N.D.	<15.0	30.0	N.D.	N.D.	20.0	<15.0	N.D.	6244.4	
HFA sol extract	99.0	17.6	1001.0	253.0	<11.0	426.0	121.0	<55.0	N.D.	N.D.	<33.0	1100.0	N.D.	N.D.	330.0	<33.0	N.D.	6257.8	
Residue	9.0	66.8	260.3	1961.0	8.8	42.5	N.D.	208.3	N.D.	N.D.	17.5	2095.0	N.D.	N.D.	467.5	27.5	N.D.	***	0.0971

***HF attack No As

396 ug

TABLE III B

ARTICULATE TEST I Wt. / ml.	cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Oo	Fe	K	Mg	Ni	V	Na	As (ng)	Residue wt.
FRUIT IPA WASH PT-(1) - 1																			
H ₂ O sol extract	129.0	27.5	1430.0	<15.0	85.0	755.0	175.0	38.5	3300	70.0	20.0	3050.0	10.0	320.0	385.0	40.0	110.0	1530000.0	
H ₂ O sol extract *	307.0	19.0	15300.0	330.0	100.0	1800.0	970.0	<50.0	4100	1090.0	350.0	23400.0	960.0	1160.0	10860.0	<30.0	170.0	366.7	0.5501
Residue	11.3	260.0	2157.5	1425.0	32.5	165.0	457.5	412.5	950.0	225.0	155.0	52000.0	115.0	545.0	4825.0	350.0	ND	***	
FILTER PT-F-1																			
H ₂ O sol extract	5.5	<5.0	.79.5	<15.0	<5.0	155.0	<25.0	<50.0	ND	ND	<15.0	25.0	ND	ND	35.0	<15.0	ND	11077.0	
H ₂ O sol extract *	700.0	23.8	2800.0	378.0	14.0	5460.0	238.0	<50.0	ND	ND	<15.0	2940.0	ND	ND	1008.0	70.0	ND	8617.8	0.2315
Residue	42.5	237.5	705.3	8986.0	64.5	330.0	ND	895.8	ND	3250.0	27.5	1695.0	ND	ND	1832.5	100.0	ND	***	
10% H ₂ SO ₄ SOLUTION PT-(1) - 2	4.0	12.5	172.0	35.0	6.0	45.0	120.0	<50.0	1100.0	295.0	70.5	620.0	75.0	58.5	155.0	<15.0	ND	12011.1	0.3469
ACID WASH PT (1)- 3	1.5	335.6	167.5	11.9	7.1	26.7	2111.7	<29.7	1455.3	50.5	23.2	641.5	38.6	38.6	210.9	<8.8	ND	6426.8	0.2090
GLASS FRIT ACID WASH	4.0	7.8	56.8	10.0	2.5	52.5	55.0	<25.0	475.0	175.0	<5.0	315.0	192.5	46.3	95.0	<7.5	ND	***	0.0376

***IF attack
No As

TABLE IV A 1200 ug

MICROTEST II (June 8/77)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V	Na	As (ppm)	Residue Wt.
FRONT IPA WASH																			
PT-(2) - 1	123.0	<5	1665.0	25.0	30.0	645.0	245.0	40.0	2350.0	15.0	20.0	3950.0	35.0	310.0	600	85.0	200.0	27444.4	
IPA sol extract	304.0	<15.0	14600.0	330.0	80.0	1640.0	830.0	<50.0	<100.0	1180.0	430.0	19200.0	1320.0	1200.0	12500.0	<30.0	745.0	133.3	.7781
H ₂ O sol extract	15.8	63.8	3857.5	4050.0	27.5	310.0	622.5	700.0	3150.0	470.0	195.0	74250.0	155.0	1035.0	7850.0	650.0	ND	***	27-12
Residue																			
FILTER																			
PT -F- 2	9.0	6.0	125.5	20.0	<5.0	305.0	<25.0	85.0	ND	ND	<15.0	20.0	ND	ND	140.0	30.0	ND	111000.0	
IPA sol extract	63.8	<10.0	4737.5	275.0	12.5	3562.5	250.0	<50.0	ND	ND	62.5	3737.5	ND	ND	1300.0	100.0	ND	30958.3	0.0938
H ₂ O sol extract	47.5	3.75	6395.3	13986.	3.25	242.5	ND	1520.8	ND	4200	15.0	2170.0	ND	1257.5	705.0	145.0	ND	44.86	5
Residue																			
ZINGER SOLUTION																			
PT (2) - 2	3.0	8.5	42.0	15.0	<2.5	50.0	<50.0	<50.0	1000.	90.0	10.5	105.0	60.0	20.0	25.0	<15	ND	21344.4	*.1276
ACID WASH																			
PT () - 3	3.2	261.2	25.2	<8.8	2.6	29.4	1555.6	<29.4	880.5	58.7	<5.0	149.7	64.6	13.5	26.4	<8.8	ND	9912.0	1.1012
GLASS FRIT ACID WASH	1.8	42.3	101.3	50.0	12.8	30.0	127.5	<25.0	500.0	850.0	7.5	1975.0	112.5	30.0	180.0	<7.5	ND	***	.0108

***HF attack No As

TABLE IV B 254 ug

TSP - 60393

PARTICLE SIZING TEST III (Filters)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V
P.S.T. - F - 3 - 1	<0.5	4.8	27.5	5.0	1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	77.5	N.D.	N.D.	7.5	<7.5
2	<0.5	1.0	53.8	12.5	<1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	100.0	N.D.	N.D.	22.5	<7.5
3	<0.5	4.5	137.0	32.5	1.0	12.5	N.D.	<25.0	N.D.	N.D.	<5.0	242.5	N.D.	N.D.	57.5	<7.5
4	7.8	8.8	82.5	150.0	<1.0	3542.5	N.D.	<25.0	N.D.	N.D.	<5.0	52.5	N.D.	N.D.	<7.5	<7.5
5	9.8	1.8	43.0	122.5	<1.0	20.0	N.D.	<25.0	N.D.	N.D.	<5.0	17.5	N.D.	N.D.	<7.5	<7.5
6	2.3	1.5	16.3	25.0	<1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	20.0	N.D.	N.D.	<7.5	<7.5
7	1.0	6.5	77.5	30.0	<1.0	20.0	N.D.	<25.0	N.D.	N.D.	<5.0	82.5	N.D.	N.D.	17.5	<7.5
8	1.3	6.3	96.0	27.5	1.3	15.0	N.D.	<25.0	N.D.	N.D.	<5.0	140.0	N.D.	N.D.	25.0	<7.5
9	1.5	1.5	113.0	27.5	1.3	N.D.	N.D.	<25.0	N.D.	N.D.	<5.0	157.5	N.D.	N.D.	37.5	<7.5

303 32 134
 102.5 5104.5 144
 4.59 2.15 19.6 TABLE V A
 5.5 1440 303
 470 1.79

ARTICLE SIZING TEST IV (Filters)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V
.S.T. - F - 4 - 1	<.5	3.0	6.5	<7.5	<1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	50.0	N.D.	N.D.	<7.5	<7.5
2	.5	6.0	31.0	<7.5	<1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	110.0	N.D.	N.D.	22.5	<7.5
3	2.3	8.0	115.3	27.5	1.75	10.0	N.D.	<25.0	N.D.	N.D.	<5.0	360.0	N.D.	N.D.	87.5	<7.5
4	2.8	1.5	102.5	32.5	<1.0	7.5	N.D.	<25.0	N.D.	N.D.	<5.0	260.0	N.D.	N.D.	72.5	<7.5
5	2.5	6.5	85.0	27.5	1.0	10.0	N.D.	<25.0	N.D.	N.D.	<5.0	175.0	N.D.	N.D.	50.0	<7.5
6	2.3	3.5	90.5	27.5	<1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	125.0	N.D.	N.D.	37.5	<7.5
7	1.5	.8	35.3	15.0	<1.0	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	27.5	N.D.	N.D.	10.0	<7.5
8	2.5	6.5	35.3	25.0	1.25	<7.5	N.D.	<25.0	N.D.	N.D.	<5.0	42.5	N.D.	N.D.	<7.5	<7.5
9	25.8	6.5	165.5	252.5	2.25	N.D.	N.D.	<25.0	N.D.	N.D.	<5.0	32.5	N.D.	N.D.	7.5	<7.5

TABLE V B

SIZE FRACTIONATION TEST #2 (JUNE 7, 1977)

Filter Stage	Particulate Wt. mg	Total SO ₄ mg	% SO ₄
1	14.1	8.8	62.4
2	14.0	7.7	55.0
3	13.0	8.5	65.4
4	14.1	8.3	58.9
5	13.8	8.5	61.6
6	13.0	7.8	60.0
7	13.0	8.1	62.3
8	9.3	5.6	60.2
9	8.7	5.3	60.9

TABLE VI

PARTICLE SIZING TEST I (Liquid Samples)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V	Na	As	Residue Wt.
ROSE IPA WASH S.T. - (1) - 1 Residue	<0.9	<3.1	8.1	12.5	<1.6	<9.4	<31.3	<31.3	<62.6	<15.7	<6.3	9.4	9.4	<3.1	<9.4	<9.4	ND	**	.0019
CYCLONE IPA WASH S.T. (1) - 2 Residue	1.3	4.1	86.1	15.7	3.8	37.6	<31.3	<31.3	<62.6	40.7	<6.3	78.3	68.9	8.8	50.1	<9.4	ND	**	.0154
INDST IPA WASH S.T. (1) - 3 Residue	2.2	13.5	67.9	25.0	7.5	15.7	<31.3	<31.3	93.9	59.5	<6.3	360.0	9.4	11.9	72.0	<9.4	ND	**	0.2654

**Insufficient sample

TABLE VII A

PARTICLE SIZING TEST II (Liquid Samples)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg	Ni	V	Na	As	Residue wt.
PROBE IPA WASH P.S.T. - (2) - 1 Residue	4.1	13.5	266.1	34.4	8.5	50.1	34.4	<31.3	<62.6	59.5	6.6	381.9	9.4	25.7	100.2	<9.4	9.4	**	0.0074
CYCLONE IPA WASH P.S.T. (2) - 2 Residue	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**	160	
INLET IPA WASH P.S.T. (2) - 3 Residue	1.3	4.1	21.6	25.0	<1.6	9.4	<31.3	<31.3	<62.6	28.2	<6.3	40.7	3.1	4.7	12.5	<9.4	9.4	**	0.3415

**Insufficient sample

TABLE VII B

109-

ARTICLE SIZING TEST III (Liquid Samples)	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Si	Ca	Co	Fe	K	Mg'	Ni	V	Na	As	Residue Wt.
PROCBE IPA WASH P.S.T. - (3) - 1 Residue	2.2	<3.1	58.8	15.7	2.5	823.2	<31.3	<31.3	93.9	93.9	<6.3	25.0	15.7	12.2	75.1	<9.4	ND	**	0.0455
CYCLONE IPA WASH P.S.T. (3) - 2 Residue	6.3	8.8	450.4	84.5	16.9	579.1	72.0	<31.3	281.7	84.5	6.9	441.3	21.9	79.2	200.3	<9.4	ND	**	0.0105
INLET IPA WASH P.S.T. (3) - 3 Residue	1.6	5.3	48.8	31.3	1.6	131.5	<31.3	<31.3	<62.6	34.4	<6.3	84.5	6.3	14.4	28.2	<9.4	ND	**	.0056

** Insufficient sample

Table VII C

APPENDIX 3
SULFUR DIOXIDE EMISSIONS DURING
SUPERSTACK TESTING - JUNE, 1977

INCO

Environmental Control
Department
Ontario Division

August 25, 1977

Ministry of the Environment,
Industrial Abatement,
469 Bouchard Street,
Regency Mall,
Sudbury, Ontario.

Attention: Mr. E. W. Piche

Re: Sudbury Environmental Study

Dear Mr. Piche:

In reply to your letter of July 12, 1977 please find the data requested pertaining to the June 1977 study.

1. The average emission rate from the 1250' stack during the period June 1, 1977 to June 23, 1977 was 3315 STPD.

2. The emission rates for the test period are as follows:

June 3, 1977		
15:00 h to 16:00 h	2216	STPD
June 5, 1977		
15:00 h to 16:00 h	3516	STPD
16:00 h to 17:00 h	4138	"
17:00 h to 18:00 h	4290	"
18:00 h to 19:00 h	4270	"
19:00 h to 20:00 h	4615	"
20:00 h to 21:00 h	4359	"

.../2

-2-

	June 6, 1977	
Particulate #1	08:00 h to 09:00 h	4242 STPD
	09:00 h to 10:00 h	<u>4205</u> "
	10:00 h to 11:00 h	NA "
	11:00 h to 12:00 h	5010 "
	12:00 h to 13:00 h	<u>4367</u> " <i>✓</i>
	13:00 h to 14:00 h	4409 "
	14:00 h to 15:00 h	4264 "
	15:00 h to 16:00 h	3480 "
	16:00 h to 17:00 h	<u>4066</u> " <i>✓</i>
Acid 1	June 7, 1977	
	09:00 h to 10:00 h	3497 STPD <i>✓</i>
	10:00 h to 11:00 h	3919 "
	11:00 h to 12:00 h	<u>3778</u> " <i>✓</i>
	12:00 h to 13:00 h	3449 "
	13:00 h to 14:00 h	2876 "
	14:00 h to 15:00 h	<u>3718</u> " <i>✓</i>
	15:00 h to 16:00 h	3355 "
	16:00 h to 17:00 h	<u>3524</u> " <i>✓</i>
Particulate #2	June 8, 1977	
	05:00 h to 06:00 h	3785 STPD
	06:00 h to 07:00 h	4266 "
	07:00 h to 08:00 h	4090 "
	08:00 h to 09:00 h	4774 "
	09:00 h to 10:00 h	<u>3936</u> " <i>✓</i>
	10:00 h to 11:00 h	4161 "
	11:00 h to 12:00 h	3439 "
	12:00 h to 13:00 h	<u>3366</u> " <i>✓</i>
Part Size	13:00 h to 14:00 h	3470 "
	14:00 h to 15:00 h	3138 "
	15:00 h to 16:00 h	2892 "
	16:00 h to 17:00 h	<u>3124</u> " <i>✓</i>
	17:00 h to 18:00 h	2690 "
Acid #2	June 9, 1977	
	09:00 h to 10:00 h	<u>3021</u> STPD <i>✓</i>
	10:00 h to 11:00 h	2622 "
	11:00 h to 12:00 h	1594 "
	12:00 h to 13:00 h	<u>1729</u> " <i>✓</i>
	13:00 h to 14:00 h	1424 "
	14:00 h to 15:00 h	1742 "
	15:00 h to 16:00 h	2065 "
	16:00 h to 17:00 h	<u>2370</u> " <i>✓</i>

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June 10, 1977	
05:00 h to 06:00 h	2969 STPD 15
06:00 h to 07:00 h	2605 "
07:00 h to 08:00 h	2203 " 19
Part Size #3	1962 "
08:00 h to 09:00 h	

28.9

June 14, 1977	
11:00 h to 12:00 h	1756 STPD
12:00 h to 13:00 h	1770 " 20
13:00 h to 14:00 h	1769 "
14:00 h to 15:00 h	1647 "
15:00 h to 16:00 h	1347 "
16:00 h to 17:00 h	1997 "
17:00 h to 18:00 h	2124 " 21

28.78

June 18, 1977	
08:00 h to 09:00 h	3289 STPD
09:00 h to 10:00 h	3752 " 22
10:00 h to 11:00 h	4170 "
11:00 h to 12:00 h	4375 " 23
12:00 h to 13:00 h	4149 "
13:00 h to 14:00 h	3457 "

28.55

$\Sigma = 3288 \text{ STPD}$
std dev 9.67

June 19, 1977	
12:00 h to 13:00 h	3503 STPD.
13:00 h to 14:00 h	3656 "
14:00 h to 15:00 h	3691 " 24
15:00 h to 16:00 h	3271 "

28.52

3 & 4. Specific charts for % SO₂, temperature, and velocity pressure as measured by our continuous monitoring station at the 267' elevation of the 1250' stack are attached.

5. As you are aware, continuous emission monitoring for IORP stack emissions is not available. Mass balances for these days indicate the following emissions:

June 13, 1977	192 Tons SO ₂
June 16, 1977	205 Tons SO ₂

During your testing period on June 13, 1977 the Nickel Refinery Converter Plant was not operating.

On June 16, 1977 the NRC (Nickel Rotary Converter) was operating normally with the Dupont SO₂ analizer operating from 09:15 hours to 12:55 hours during the blow and reduction phase and from 14:30 hours to 16:25 hours during the charge phase. The total SO₂ emissions from the converter plant during these two time periods were 8.93 M.T. and 1.35 M.T. respectively.

6. The Hartman-Braun analizer was not operated during this time period.

7. A summary of operating conditions at the IORP and Nickel Refinery are attached.

If we can be of further assistance in supplying data related to this study, please feel free to contact us at your convenience.

Yours very, truly,



H. R. Butler, P. Eng.,
Supervisor,
Environmental Control

BJB/sc
Attach.

APPENDIX 4
CALIBRATION OF PITOBES USED
DURING INCO SUPERSTACK TESTING
JUNE 1977



Ontario

-67-

Area Code 416
965-5776

Ministry of the
Environment

Office Location -
880 Bay Street,
4th Floor,
Toronto, Ontario.
M5S 1Z8

Date: May 25th, 1977.

MEMORANDUM

To: FILE - Inco, Sudbury, Ontario.

From: John McDonald,
Source Assessment Unit,
Technology Development & Appraisal Section,
Air Resources Branch.

Subject: CALIBRATION OF INCO SUPERSTACK SAMPLING PROBES

On May 19th, members of the Source Assessment Unit took 3 Inco probes to the University of Toronto wind tunnel for calibration. A fourth probe, 25 ft. in length, was not taken because the wind tunnel could not accommodate its length.

Two of the probes (designated as #3 and #4 by Inco) were modified to accommodate the Anderson impactor and were calibrated with this unit in place. The Anderson assembly included a precyclone and a 1/8 inch sampling nozzle. The remaining probe was calibrated using two 1/4 inch sampling nozzles provided by Inco. Inco did not have a 3/16 inch nozzle and MOE's nozzle of this size would not fit on this probe; thus, calibration of the probe with this nozzle was impossible. All S-type pitots on the probes were calibrated against an Airflow Developments Unity Standard pitot tube. Barometric pressure was 29.64" Hg, relative humidity was 48%, and ambient temperature was 74-75°F.

Experimental Results:

Tables 1 and 2 and Graphs 1 and 2 give the data from calibration of probes 3 and 4 with the Anderson impactor. The coefficient C_v , derived from these experiments, was higher than anticipated ($\approx .90$). This could be due to the proximity of the S-type pitot tips to the cylindrical precyclone, and the resultant high vacuum on the downstream leg. Indeed, it was noted during the testing that connection of the downstream input caused a large reduction in the manometer reading when compared to the reading due to stagnation pressure in the upstream leg alone. Overall alignment of the components on Probe 3 appeared superior to that in probe 4.

The calibration of the remaining probe with the two 1/4" nozzles provided by Inco proceeded largely as anticipated. It was noted that one nozzle tip came to a finer edge than the other.

Since these nozzles were identical in all other respects, the difference between their calculated coefficients (.783 vs. .7956 for the sharp-edged nozzle) appeared to be the result of this difference in nozzle tip configuration.

Recommendations:

1. In performing the particle sizing work with the Andersen impactor, probe #3, with a C_v of .894, will be used.
2. In the particulate testing, the sharp edged Inco 1/4" nozzle will be used, with a coefficient C_v of .796.
3. If this probe is used for the acid tests and is modified to accommodate the MOE 3/16" nozzle, a coefficient of .80 will be used because of the increased bulk of the 3/16" nozzle.

JM/mll

John McDonald

John McDonald
D.M.

c.c. Mr. Ed Piche, MOE Sudbury

Mr. A. Church, Superintendent,
Smelter Process Technology,
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P0M 1N0

TABLE 1.

Calibration of Probe #3 with Andersen Head

ΔP Std.	ΔP S-Type	$\sqrt{\Delta P}$ S-Type	Velocity (ft/sec)	C_v
.648	.805	.897	54.44	.897
.468	.525	.758	46.27	.902
.343	.412	.642	39.61	.912
.223	.281	.530	31.94	.891
.162	.201	.448	27.22	.898
.094	.118	.3435	20.74	.893
.017	.165	.406	23.14	.842
.200	.241	.491	30.25	.911
.278	.358	.598	35.66	.881
.397	.484	.696	42.62	.906
.542	.670	.819	49.79	.899
.651	.814	.902	54.57	.894

$$\overline{C_v} = .8938$$

Stack Temperature (T_s) = 535°RWet Molecular Weight (M_w) = 28.81Tunnel Pressure (P_s) = 29.66" Hg

Velocity vs. Square Root Pressure Drop - S-Type Pitot, Probe #3 with Andersen Impactor

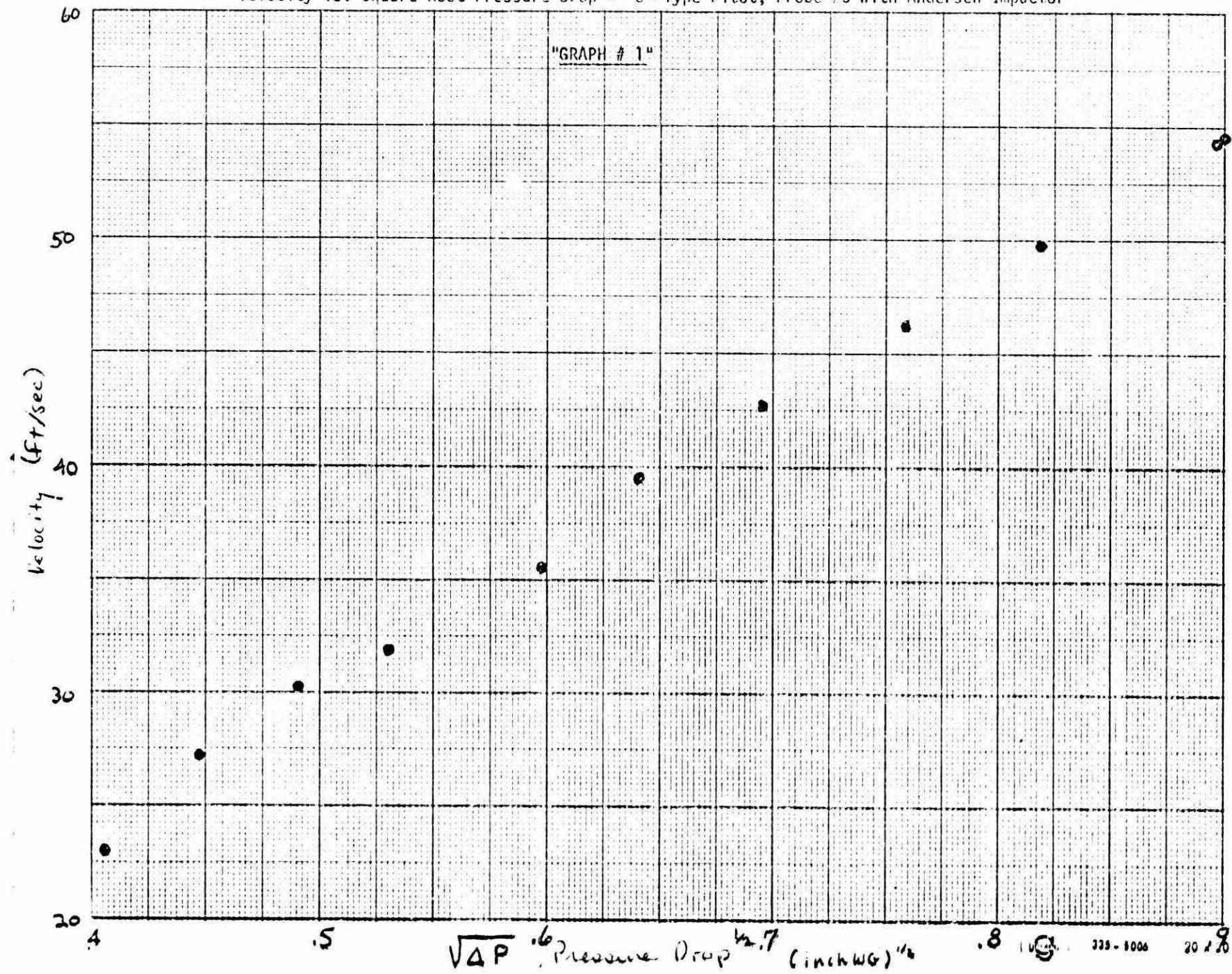


TABLE 2.

Calibration of S-Type Pitot, Probe #4 with Andersen Head

ΔP Std.	ΔP S-Type	$\sqrt{\Delta P}$ S-Type	Velocity (ft/sec)	C_v
.6	.68	.825	52.39	.94
.428	.482	.694	44.25	.94
.298	.356	.597	36.92	.915
.174	.215	.464	28.21	.900
.100	.130	.361	21.39	.877
.145	.187	.432	25.76	.880
.220	.271	.521	31.78	.901
.319	.380	.616	38.27	.916
.370	.429	.655	41.22	.930
.580	.659	.812	51.61	.940

$$\overline{C_v} = .914$$

Temperature - 535°R

Wet Molecular Weight - 28.81

Tunnel Pressure - 29.66 in Hg.

GRAPH #2 - Velocity vs. Square Root Pressure Drop - S-Type Pitot with Andersen Impactor - Probe #4

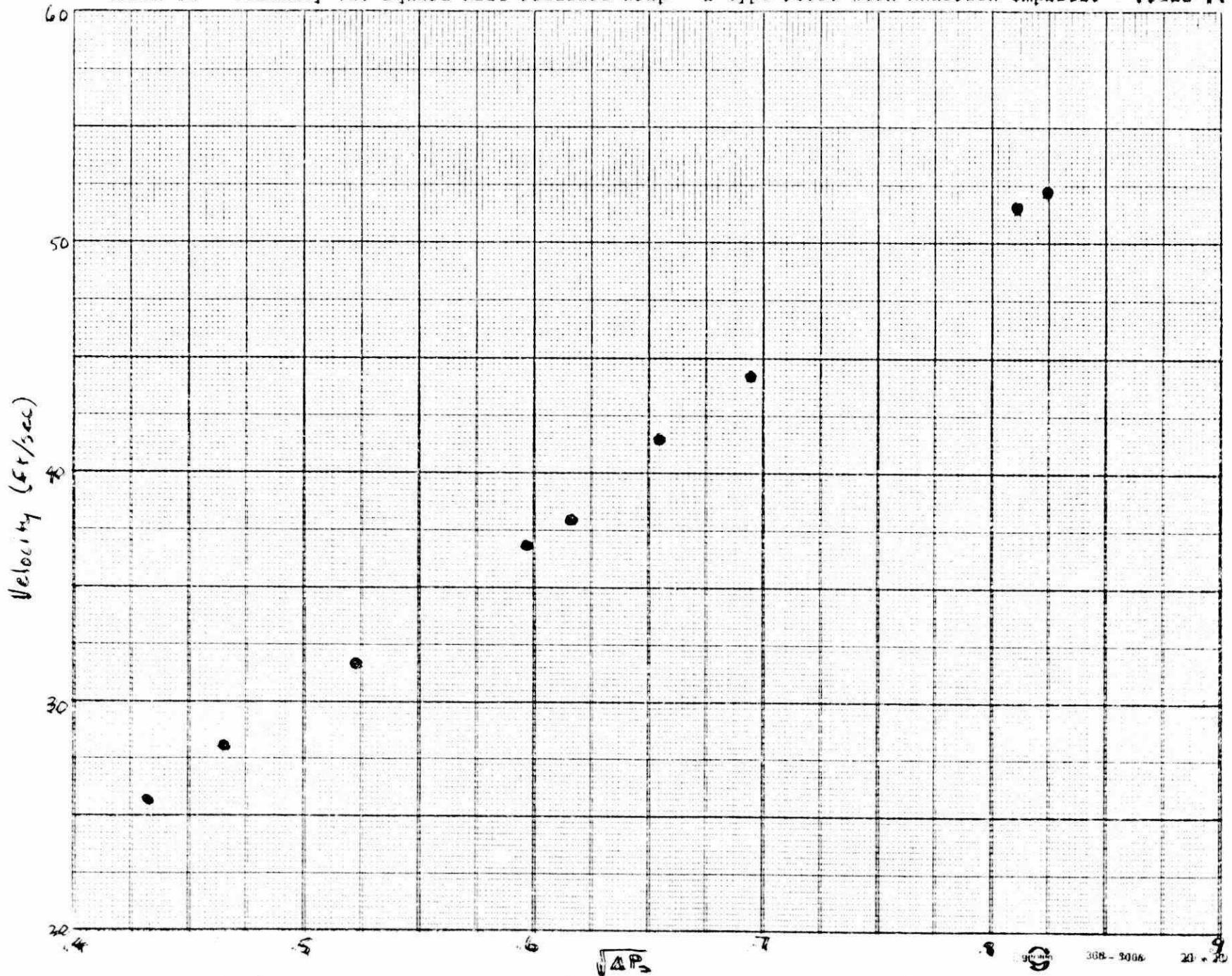


TABLE 3.

Calibration of S-Type Pitot Probe with 1/4" Nozzle

ΔP Std.	ΔP S-Type	$\sqrt{\Delta P}$ S-Type	Velocity (ft/sec)	C_v
.120	.142	.377	23.41	.791
.1925	.301	.549	29.65	.798
.280	.482	.694	35.76	.762
.370	.633	.796	41.10	.765
.519	.820	.906	48.68	.796
.611	.970	.985	52.82	.794
.430	.689	.830	44.31	.790
.317	.550	.742	38.05	.759
.223	.358	.598	31.91	.789
.144	.233	.483	25.64	.786
.083	.136	.369	19.47	.781

$$\overline{C_v} = .783$$

Tunnel Temperature (T_s) = 534°R

Wet Molecular Weight (M_s) = 28.81

Tunnel Pressure (P_s) = 29.66" Hg

GRAPH #3 - Velocity (ft/sec) vs. Square Root Pressure Drop - S-Type Pitot Probe with 1/4" Nozzle

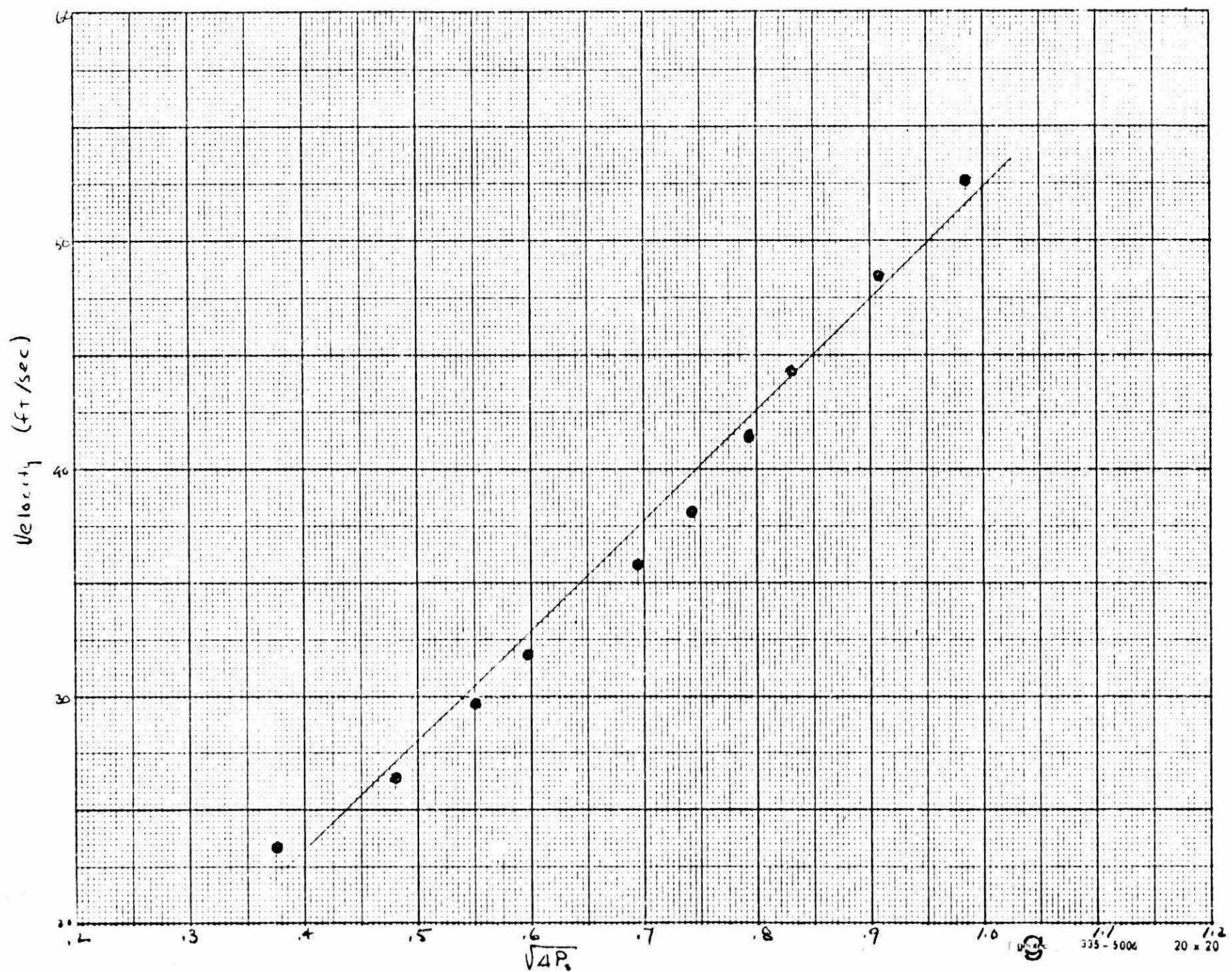


TABLE 4.

Calibration of Probe with 1/4" Nozzle - Sharp-Edge

ΔP Std.	ΔP S-Type	$\sqrt{\Delta P}$ S-Type	Velocity (ft/sec)	C_v
.610	.960	.980	52.78	.800
.430	.671	.819	44.31	.800
.290	.452	.672	36.39	.800
.228	.356	.597	32.27	.800
.150	.240	.490	26.17	.790
.080	.138	.371	19.11	.761
.271	.422	.650	35.18	.801
.379	.595	.771	41.60	.798
.512	.800	.894	48.35	.800
.616	.948	.974	53.04	.806

$$\overline{C_v} = .7956$$

Tunnel Temperature (Ts) = 534°R

Wet Molecular Weight (Ms) = 28.81

Tunnel Pressure (Ps) = 29.66" Hg

GRAPH #4 - Velocity (ft/sec) vs. Square Root Pressure Drop - S-Type Pitot Probe with Sharp Edged 1/4" Nozzle

55

Velocity (ft/sec)

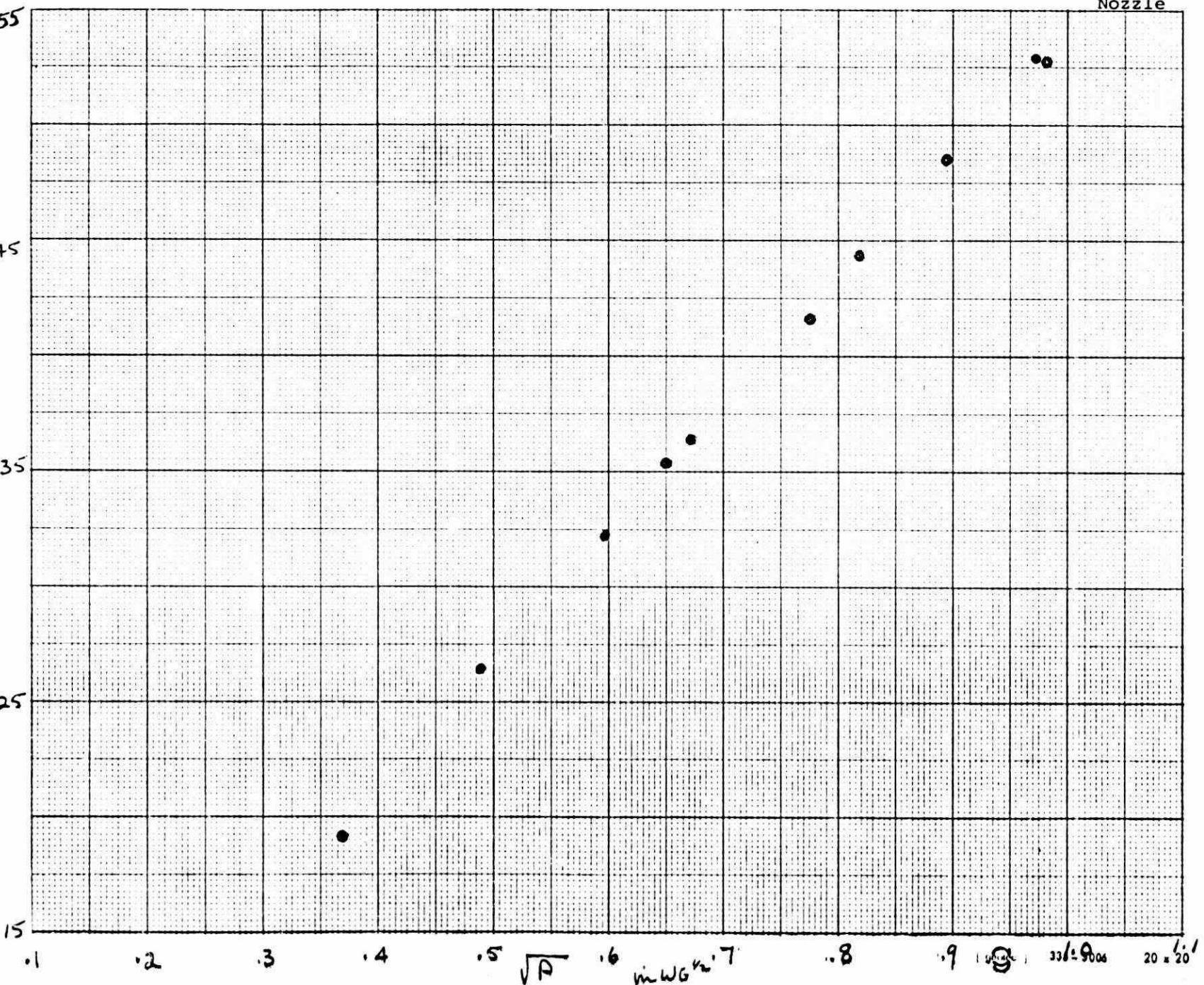
45

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APPENDIX 5

INCO - MOE LABORATORIES COMPARATIVE ANALYSES

RESULTS AND COMMENTS

1977 INCO SUPERSTACK TEST



Area Code 965-4081	Ministry of the Environment	Office Location - 880 Bay Street 4th Floor Toronto, Ontario. M5S 1Z8	135 St. Clair Avenue West Suite 100 Toronto Ontario M4V 1P5
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August 3, 1978

MEMORANDUM

To: File: 1977 INCO 380 Meter Stack Testing

From: J. McDonald, P. Eng.
Source Assessment Unit
Technology Development and
Appraisal Section
Air Resources Branch.

Subject: INCO - MOE Comparative Analyses of
Stack Samples from the 1977 program
at the INCO 380 m. Stack

Selected Samples from the 1977 sampling program at the INCO 380 meter stack in Sudbury were analyzed by both the Laboratory Services Branch, MOE, and INCO laboratory personnel. The samples and related analyses are listed below.

<u>Test</u>	<u>Samples</u>	<u>Analyses</u>
ACID II	Washings & Filter Media Extracts	Sulfate
PARTICULATE II	Washings & Filter Media Extracts	Trace Metals
PARTICLE SIZE III	Washings only	Trace Metals
PARTICLE SIZE IV	Filter Media Only	Trace Metals
BLANKS	As Listed in Table 5	Trace Metals

Referring to Table I, analysis for sulfate from ACID Test II samples, the INCO lab found a considerably smaller amount of isopropanol soluble sulfate than did MOE (60.7 mg. compared to 86 mg.). If the INCO total was used in calculating acid emission data, a significant decrease would result. Thus, although the current acid level detected by MOE was considered to be the lower limit (\approx 12 ppm), the INCO analyses indicate that a value of approx. 8 ppm. for acid emissions for this test is conceivable.

Two major discrepancies are apparent in Table 1. The first is in the analyses of the IPA Front End Wash; where MOE found 29.9 mg. SO_4^{2-} , INCO detected 48 mg. The reverse occurred in the analyses of the IPA extract from the third impinger; where MOE found 42.7 mg, INCO found .3 mg. Assuming that sample degradation is not a significant factor, these results raise further questions regarding the acid emissions determined in the 1977 test program.

Table II compares analyses of washing and filter media extracts for trace metals performed by INCO and MOE lab. Significant differences in analysis occurred for the following elements: cadmium, aluminum, calcium, potassium and magnesium. In all these cases, the INCO determinations were higher than MOE's; for aluminum, potassium and calcium the difference in corresponding emission rates varied by factors as great as 8 to 10 times. However, in the case of Al, Ca, K and Mg, the largest amount of each of these elements was found in the filter residue aliquot as shown in Table II (Bottle 5C). Table V gives levels of these elements found in the residue of a 'blank' filter, and again, values for these elements are quite high and correspond very closely to those given in Table II. Perhaps this 'background' value was inadvertently not subtracted from the amounts determined in the INCO analyses listed in Table II. As Table VI illustrates, the Gelman Spectro Grade A filters typically contain very significant amounts of aluminum, calcium, magnesium and lesser amounts of potassium. Thus the background levels of these elements found in the blanks are consistent with the composition of these filters.

No comparative value is given for the arsenic emissions determined by INCO in Table II, since the procedure was not identical to an earlier one used at the MOE laboratory. MOE concluded that their earlier procedure had underestimated arsenic quantities and, since there was in some cases only enough sample volume for one analysis, MOE requested that INCO use a modified procedure to determine arsenic. Samples retained by MOE (PARTICULATE I and ACID I) were reanalysed by the modified procedure and the new arsenic level included in the TDA evaluation of the 1977 report. The amount of arsenic detected by INCO was almost double the higher of the MOE values; the third value was an order of magnitude lower than the smaller of the other two.

Table III gives trace metal analyses of the glass fibre substrates used in the Andersen impactor. Again, the material is Gelman Spectrograde A glass fibre and the blank analyses in Table V show large quantities of Al, Ca, K, and Mg. INCO determinations for these metals are much higher; MOE did not detect any of the four elements in the samples analyzed.

Table IV gives a trace metal analyses of washings from partic sizing test III. Quantities detected were much smaller than those found in the particulate testing, and in most cases, MOE and INCO data were quite comparable. Again INCO detected significant amounts of sodium where MOE did not. Similarly, the amount of vanadium detected by INCO was greatly in excess of the limit of less than .009 mg. found by MOE. Amounts of copper, zinc, iron and nickel detected between the two labs were quite comparable.

Recommendations

- 1) If levels of aluminum, calcium, potassium and magnesium emitted from the 380 meter INCO stack are considered critical, the anomalies between INCO and MOE analysis of these metals should be investigated further.
- 2) Arsenic data obtained during the 1977 program at the 380 meter stack are inconsistent and every attempt should be made to clarify and review the analytical procedure prior to any arsenic determinations in 1978.

- 3) Acid sampling procedure and analytical technique must be scrutinized carefully prior to the 1978 sampling program. Sulfuric acid emissions obtained in 1977 should be taken as a lower limit until confirmed by further testing.
- 4) The comparative analyses program has merit and should be continued for any future sampling programs at the 380 meter stack.

JM/gf

John McDonald
John McDonald

cc: B. Foster
W. Chan
S. Stevens
T. VanRossum-N.E. Reg.
V. Ozvacic
E. Piché

TABLE I

ACID TEST II	No	Vol Ml.	SO ₄ Mg	All Quantities in Milligrams
Front IPA Wash at (2) - 1				INCO/MOE
IPA Sol Extract	3F	64	48/29.9	
H ₂ O Sol Extract	4F	50	58/62.5	
Residue	2	25	1.4	
First Impinger at (2) - 2				
IPA Sol Extract	14F	50	2.6/1.7	
H ₂ O Sol Extract	15F	61.8	58 /13.8	
Residue	11	25	.06	
Second Impinger at (2) - 3				
IPA Sol Extract	18F	50	.2/1.2	
H ₂ O Sol Extract	19F	61.8	14.0/5.7	
Residue	12	25	.05	
Third Impinger at (2) - 4				
IPA Sol Extract	22F	50	.3/42.7	
H ₂ O Sol Extract	23F	53.6	1.3/1.8	
Residue	14	25	.04	
Acid Wash at (2) - 5	2A	32.9	7.9	
Filters at F - 2			0	
IPA Sol Extract	35F	50	9.6 /10.5	
H ₂ O Sol Extract	36F	110	28.5 /28.6	
Residue	36C	25	5.9	
Total IPA Soluble SO ₄ -MOE/INCO			86/60.7	

PARTICULATE TEST II	Bottle No	Volume ml	All Quantities in Milligrams																			
			Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Ca	Co	Fe	Ni	K	Na	V	Mg	Te	As	Se	
Front IPA Wash Pt (2) - 1																						
IPA Sol Extract	7F	50	.123	.106	.069	1.67	.025	.030	.645	.245	.04	.015	.020	3.95	.600	.035	.208	.085	.281	.184	7.5	.008
H ₂ O Sol Extract	8F	100	.304	.323	.03	14.6	.330	.080	1.64	.830	.06	1.18	.430	19.20	11.50	1.34	2.21	.31	.200	.001	.171	.001
Residue	4	25	.016	.016	.064	3.86	4.05	.027	.310	.623	.70	.47	.195	74.25	7.85	.155	ND	.650	1.035			
Filter PT - F -																						
IPA Sol Extract	39F	50	.009	.006	.02	.125	.02	.005	.305	.1	.085	ND	.014	.020	.016	.017	.325	.2	.010	.050	.743	.007
H ₂ O Sol Extract	40F	125	.064	.685	.04	4.74	.275	.013	3.56	.250	.07	ND	.062	3.737	1.30	ND	ND	.100	ND	.005	.148	.005
Residue	5C	25	.048	.073	.003	6.39	13.99	.003	.243	ND	1.521	4.20	.015	2.170	.705	ND	ND	.145	1.257			
Impinger Solution PT (2)-2	6A	50	.003	.003	.008	.042	.015	.005	.050	.1	.03	.090	.011	.105	.025	.060	ND	.020	NA	.121	.114	
Acid Wash PT-(2) - 3	4A	29.3	.003	.003	.261	.025		.0026	.029	1.556	.02	.059	.026	.150	.024	.086	.508	.2	.027			
Glass Frit Acid Wash	9A	25	.002	.002	.042	.101	.050	.013	.030	.128	.02	.850	.007	1.975	.180	.113	ND	.030		.003	.666	.018
TOTAL mg.	MOE INCO		.571	1.217	.386	28.93	31.54	18.82	.169	6.814	3.631	2.345	6.86	.741	105.57	23.32	1.747	1.01	3.86			
EMISSIONS (grams/sec)	MOE INCO		.228	.537	.154	.208	12.58	11.54	7.48	.067	2.72	1.45	.935	2.73	.295	42.11	9.30	.697	.176	.403	1.59	.76

TABLE III

All Quantities in Milligrams

PARTICLE SIZING TEST III	Bottle No	Volume ml	Cd	Cr	Cu	Pb	Mn	Zn	Al	Bi	Ca	Co	Fe	Ni	K	Na	V	Mg	Te	As	Se			
(Filters)																								
P.S. T. - F - 1	60B	25	.001	.01	.0065	.010	.01	.005	.007	4.32	.02	6.67	.005	.050	.135	.007	1.40	17.5	.1	2.80	NA			
2	61B	25	.001	.01	.037	.036	.01	.004	.010	3.75	.02	5.58	.005	.110	.023	.206	.029	1.22	16.4	.1	2.24	NA		
3	62B	25	.0023	.008	.115	.0215	.0018	.008	.006	.021	4.43	.02	6.58	.006	.360	.088	.481	.108	1.40	18.5	.1	2.98	NA	
4	63B	25	.0028		.102	.0325		.010		.004	.023	3.98	.02	5.79	.005	.260	.073	.411	.078	1.27	16.6	.1	2.50	NA
5	64B	25	.0025		.085	.0275	.001		.006	.023	4.43	.02	6.12	.005	.175	.050	.279	.062	1.35	18.1	.1	2.71	NA	
6	65B	25	.0023		.091	.0275		.005	.016	3.86	.02	5.75	.005	.125	.038	.049	1.30	16.5	.1	2.53	NA	.008 .001		
7	66B	25	.0015		.035	.015		.004	.013	4.43	.02	6.29	.005	.028	.010	.107	.018	1.42	18.3	.1	2.81	NA	.008 .001	
8	67B	25	.0025		.035	.025	.0013		.006	.020	4.43	.02	6.08	.005	.043	.014	.125	1.30	17.3	.1	2.61	NA	.008 .001	
9	68B	25	.0258	.0065	.165	.252	.0023		4.01	5.45	.039	5.00	.005	.033	.008	.128	.016	3.10	13.6	.1	.894	NA	.032 .001	
TOTAL			MOE	INCO		.666	.407							.29			.381							

NA = Not Analysed

ND = Not Detected

TABLE IV
All Quantities in Milligrams

NA = Not Analysed

ND = Not Detected

All Quantities in Milligrams

TABLE V: ANALYSES OF 'BLANKS' FOR SELECTED METALS

TABLE VI
Typical Chemical Composition
Of Glass Fibre Filters

CHEMICAL COMPONENT	GLASS TYPE				
	Typical Borosilicate*	Gelman Type I †	Gelman Type II †	Spectro Type †	Micro Quartz △
SiO ₂	57.9	54.3	57.9	63.4	99.2
B ₂ O ₃	10.7	8.0	10.7	5.6	-
Fe ₂ O ₃	5.9	-	-	-	-
Al ₂ O ₃	10.1	14	5.2	5.2	-
Na ₂ O		0.5	10.1	14.0	-
K ₂ O	2.9	0.5	2.9	1.1	-
CaO	2.6	17.4	2.6	9.3	-
MgO	0.4	4.9	0.4	9.3	-
BaO	5.0	-	5.0	-	-
ZnO	3.9	-	3.9	-	-
F	0.6	-	-	-	-
TiO	-	0.4	0.09	0.02	-
Na ₂ SO ₄	-	0.01	0.2	0.2	-
Fe	-	0.2	0.6	0.7	-

* Whatman catalogue 60M-776-TPC

† Reference (4)

△ Reference (5)

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